REPORT RESUMES

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INDUSTRIAL RADIOGRAPHY COURSE, INSTRUCTOR'S GUIDE, VOLUME 1.
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DESCRIPTORS- *CURRICULUM GUIDES, *TEACHING GUIDES, *TRADE AND INDUSTRIAL EDUCATION, *RADIOGRAPHERS, *RADIATION, TECHNICAL EDUCATION,

THE PURPOSE OF THE GUIDE IS TO GIVE MAXIMUM ASSISTANCE TO INSTRUCTORS IN PLANNING THE TRAINING OF LICENSED INDUSTRIAL RADIOGRAPHERS. IT WAS DEVELOPED BY THE ENGINEERING EXTENSION SERVICE, TEXAS AGRICULTURAL AND MECHANICAL UNIVERSITY, COLLEGE STATION, TEXAS. THE 21 UNITS INCLUDE (1) INDUSTRIAL APPLICATIONS, (2) NONDESTRUCTIVE TESTING METHODS, (3) PROFESSIONAL ETHICS, (4) RADIATION DETECTION INSTRUMENTS, (5) RELATED MATHEMATICS, (6) EFFECTS OF RADIATION, (7) IRON AND STEEL, (8) APPLICATIONS OF WELDING, (9) CONTAMINATION TESTS, (10) FILM EXPOSURE FACTORS, (11) STANDARDS AND LICENSES, (12) REQUIRED RECORDS AND REPORTS, (13) EQUIPMENT, (14) FILM, (15) MEASUREMENT OF RADIOGRAPHIC SENSITIVITY, AND (16) TRANSPORTATION OF RADIOACTIVE MATERIALS. THE 114 LESSON PLANS EACH GIVE SUBJECT, PURPOSE, TEACHING AIDS, REFERENCES, PREPARATION OF THE LEARNER, INSTRUCTIONAL TOPICS, APPLICATION, TEST, AND SUMMARY. STUDENTS SHOULD BE 18 YEARS OLD AND HIGH SCHOOL GRADUATES WHO, WHENEVER POSSIBLE, POSSESS PROFICIENCY IN MATHEMATICS, PHYSICS, AND CHEMISTRY. THEY MUST NOT BE ACCIDENT PRONE, EMOTIONALLY UNSTABLE, OR HAVE A TENDENCY TO PANIC. TOTAL LESSON TIME REQUIRED IS 242 HOURS. A COMPANION VOLUME (VT 003 503) CONTAINS 52 INFORMATION SHEETS RELATED TO THE LESSON PLANS, A GLOSSARY, AND A BIBLIOGRAPHY OF BOOKS AND FILMS. (EM)

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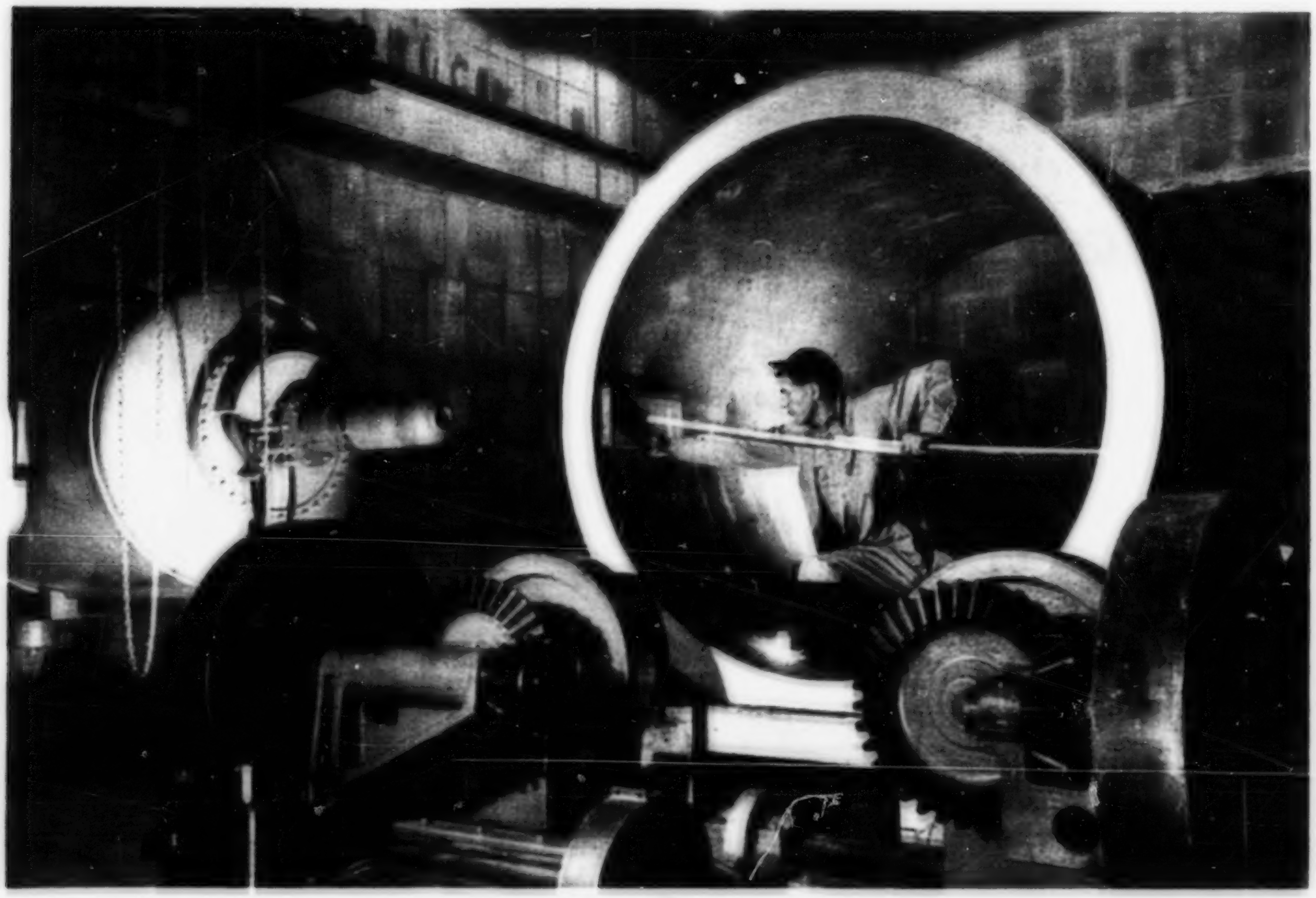
INSTRUCTORS' GUIDE Volume 1

INDUSTRIAL RADIOGRAPHY COURSE



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INSTRUCTORS' GUIDE Volume 1

INDUSTRIAL RADIOGRAPHY COURSE

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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INTRODUCTION

Anyone planning to teach the course outlined in this guide should briefly review his objectives recognizing the fact that the field of radiography has not been reduced to an exact science capable of providing repeatable, predictable and non-variable responses to tests and scientific exploration.

He must recognize as well the greater importance of interpreting the findings of a test as compared to the more accurate pictorial representation of the conditions being examined.

The basic objectives of the course previously referred to are simply these:

To train adept individuals in the appropriate techniques of inspecting parts, materials and processes using for this purpose radioactive material or radiation producing equipment including all technical and practical applications related thereto, that is, film exposure, film processing, interpretation and evaluation.

To develop individual competency in the art or science of radiography to a degree that the individual can meet all of the requirements for a license that may be issued by an appropriate state licensing authority or the U. S. Atomic Energy Commission.

In order to give maximum assistance to the instructor in meeting the objectives of the course and in the accomplishment of his teaching assignment this instructors guide outlines in detail all information, helps, guides and suggestions that he may need in acquitting his responsibility.

The lesson plans contained herein provide the instructor with essential information relating to each topic together with other helpful aids and ready references for his use.

These lessons are not intended as inflexible guides or stereotyped formats but should be used as suggested and when coupled with the skilled techniques and professional ability of the teacher can be most helpful in allowing for each individuals own personal treatment of the subject matter being careful, however, that a thorough course coverage is effected.

Topic arrangement has been planned and should be adhered to whenever possible providing for the orderly development of procedural knowledge and technical aptitude.

The instructor must take sufficient time to review each lesson plan prior to its use giving himself the opportunity of procuring the suggested teaching aids, films or whatever else is suggested therein.

Several films are listed as essential conveyors of information, however, the instructor should be aware of the need for scheduling these well in advance of the anticipated date of showing to insure adequate time for delivery.

It might be stated merely as a refresher note that good instructors have no difficulty in placing the proper emphasis on the use of films, visual aids and other teaching devices, never using them in place of sound teaching techniques but rather to emphasize and stress various elements of the program or as a device for effective summarization of course material.

In addition to the aforementioned related technical information lesson plans, manipulative lesson plans, and experiment exercises are also included in this guide. These are used in conjunction with laboratory exercises and planned practice sessions. Their use and application is quite similar to those previously discussed and will be found to be quite helpful in the operation of the training program.

Appropriate tests and examinations are also included for the instructor's use and should be applied in their respective sequences or at such times when it is a reasonable certainty that all subject matter covered by the test has been adequately presented.

The appendix of this instructors guide also contains a glossary of terms, bibliography, film list, selected reference material, specifications, drawings and suggested instructional aids.

ENROLLEE QUALIFICATIONS

The basic or fundamental qualifications of a radiographic trainee are a minimum age of 18 with a capability of rendering mature and sound judgements, making intelligent decisions and correct interpretations. The individual must also possess good health and be physically able to perform routine manually dextross operations.

The prospective student should have a high school education or its equivalent. Whenever possible it is desirable that the trainee possess or develop proficiency in algebra, trigonometry, mechanical drawing, elementary physics and chemistry.

The individual should possess a reasonably neat appearance, have normally good or properly corrected vision making him capable of detecting minute structural plans in poorly lighted areas.

There must be no record of accident proneness, emotional instability or tendency to panic.

He must be ready adaptable to any work situation, be reasonably facile, completely honest and dependable.

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INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit	1
Lesson	1
Time	2 hours

SUBJECT: Radiography as an Industrial Tool

AIM (or purpose): To develop a familiarization with the various uses of penetrating radiation as it may be used by industry

TEACHING AIDS: Radiography facilities
Radiographic film of defects in welds and castings
Film of corrosion damage in piping
Sample defective parts

REFERENCES: Nondestructive Testing Handbook, Volume I, 1963, Society of Nondestructive Testing, Evanston, Ill.
Information Sheet #1 (Included in Appendix of this manual)

I. PREPARATION (of the learner)

A. As an introduction, explain the purpose of this course and briefly describe the procedures and activities in which the class will be involved during the course:
Define radiography (write it on chalkboard)
State briefly the function of a radiographer
Make comparison of medical and industrial radiography
Indicate some uses of radiography besides defect detection
Point out that some defects are not detectable by radiography

B. Introduce the aim or purpose of this lesson.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Radiography for flaw detection	1. Explain and discuss preventive maintenance programs to detect fatigue cracks, corrosion, and other service defects.
	2. Explain & discuss the code requirements for inspection of new fabrication.
	3. Explain the use of radiography for inspection of high performance equipment such as aircraft, where failure cannot be tolerated.
	4. Explain & discuss flaw detection for the improvement of manufacturing processes.
	5. Questions
B. Radiography as a gauging device	1. List the automated devices used by steel mills to control the thickness of sheet steel. Processes whereby sheet steel is gauged through detecting variation in radiation intensity as it passes through the sheet while it moves past the radiation beam.
	2. Explain the control of cigarette density by radiation gauging.
	3. Explain & discuss the measurement of corrosion damage employing the use of radiographs and instrumented radiation gauges.
	4. Sketch a typical fluid level gauging application using a "Penetron" type device.
	5. Questions
C. Other uses of radiography	1. Describe the: a. Identification of false art works b. Location of hidden objects c. Inspection of components for proper placement in electronic manufacturing
	2. Questions

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Take students on a guided tour of the school facilities and point out the various pieces of equipment used in industrial radiography.

B. Show sample of radiographs, defective welds, castings and corrosive metal loss in steel pipe.

C. Promote discussions during tour regarding the use of penetrating radiation.

IV. TEST (final check on students' comprehension of material presented)

NOTE TO INSTRUCTOR: The following essay type test questions will be given for most of the lesson plans in this course. It is suggested that the instructor use the essay questions as a guide for designing objective type test items (true-false, multiple choice, completion, matching, etc.) to be used as a printed "Pass-out" test. The testing method should be varied to maintain a high interest level.

Conduct a question and answer period on the uses of penetrating radiation for industrial purposes.

A. How can penetrating radiation measure thickness of materials?

B. How can penetrating radiation measure the relative density of a material?

C. How can penetrating radiation be used as a remote liquid level indicator and/or level controller?

D. How can penetrating radiation be used to detect the presence of internal erosion or corrosion in a pipe or vessel?

E. How can penetrating radiation detect internal flaws in opaque objects?

V. SUMMARY

A. Radiograph is a shadow image of an opaque object.

B. Radiographs cannot detect all hidden discontinuities in an opaque object.

C. Penetrating radiation has many other industrial uses.

The Next Lesson is: Industrial Applications of Radioisotopes

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit	1
Lesson	2
Time	2 hours

SUBJECT: Industrial Applications of Radioisotopes

AIM (or purpose): To develop an understanding of the many industrial uses of radioisotopes

TEACHING AIDS: Film: Industrial Applications of Radioisotopes, (1960), 57 mins., 16 mm, sound, U.S. Atomic Energy Commission

EQUIPMENT: Film projector and screen

I. PREPARATION (of the learner)

Introduce the film - name, length, color, etc. stress lesson aim,

A. The following points should be observed by the student when viewing the film:
   1. The three fundamental divisions of industrial usage
   2. The various types of gauging devices and how they differ; i.e., the through - transmission, the backscatter, the beta and the gamma ray gauges
   3. Methods of flow measurement using radioisotopes
   4. Uses of flow gauges and fluid level indicators
   5. The various types of radiographic exposure devices shown in the film

B. The above points will give a better understanding of the many applications of industrial radioisotopes.

C. After the film is shown a test will be given regarding the previously discussed items.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
"Industrial Applications of Radioisotopes"	Show the film

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Discuss the film - with the students and emphasize the following points:

A. The three fundamental classifications of industrial radioisotope applications:

1. Gauging
2. Radiography
3. Tracing

As each of these areas of work are discussed the subject should be amplified and elaborated upon.

B. The principles and applications of:

1. Back scatter gauges
2. Beta gauges
3. Gamma gauges
4. Through-transmission gauges
5. Fluid densitometers
6. Fluid level gauges

C. The different types of gamma exposure devices seen in the film and the various applications of each,

D. Tracer applications

E. If certain points need additional clarification reshow the film or portions of it.

IV. TEST (final check on students' comprehension of material presented)

Note: Oral Quiz

A. What are the three basic categories or classifications of industrial isotope applications?

B. Explain the difference between a back scatter and a through transmission thickness gauge.

C. What is the field of application of a beta gauge? Of a gamma gauge?

D. Why is it necessary to have different types of gamma ray exposure devices in radiographic applications? Why are different isotopes used?

E. How can a volume of fluid flow be measured using radioisotopes?

V. SUMMARY

A. Industrial applications of radioisotopes are being applied by manufacturers of rubber, steel, plastics, paper, nylon, foods, cement, ships, oil and automobiles.

B. Tracer materials must be handled carefully and controlled because they are not usually recovered.

C. Beta emitters are used for penetrating thin materials having a low relative density.

D. Gamma emitters are used in radiography and in measuring thick, high density materials.

The Next Lesson is: Ultrasonic Nondestructive Testing

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 2
Lesson 1
Time 1 hour

SUBJECT: Untrasonic Nondestructive Testing

AIM (or purpose): To develop understanding of nondestructive testing methods outside the field of industrial radiography

TEACHING AIDS: Ultrasonic test equipment
Ultrasonic test blocks
Sample defective parts
Transducers

REFERENCES: Nondestructive Testing Handbook, Volume II, 1963, Society for Nondestructive Testing, Evanston, Ill.

I. PREPARATION (of the learner)

Explain how this method of testing can be useful to the radiographer:

A. As a supplement to radiography

B. Where radiography can not be effected

C. When a less expensive method of testing is needed

D. As a thickness test where only one side of the material is exposed

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Pulse echo testing 1. Transmission 2. Reception 3. Reflection	1. Draw a chalkboard sketch to illustrate the introduction of sound into a material, its reflection, and reception by the instrument. 2. Explain the pulsing of the sound to allow time for receiving the reflected signal. 3. Questions
B. Ultrasonic transducers	1. Explain the piezoelectric phenomenon: Term means "Pressure Electric" Pressure applied to Quartz crystal causes a potential difference between its opposite sides; ultrasonic transducer contains such a crystal. 2. Describe the construction of transducers including the wear-plate, dampening materials, and electrical connections. 3. Display typical transducers. 4. Questions
C. Wave propagation 1. Longitudinal 2. Shear 3. Surface 4. Lamb	1. Illustrate and define on chalkboard the various wave forms. 2. Illustrate applications for each mode or wave form. 3. Questions
D. Acoustic impedance	1. Explain sonic reflections in terms of accoustical mismatch. 2. Explain why some materials reflect part and transmit part of the incident beam. 3. Explain the decay of the sound intensity as the beam travels farther away from the transmitter. 4. Questions

II. PRESENTATION (continued)

Instructional Topics	Things to Remember to Do or Say
E. Applications for sonic testing 1. Flaw detections 2. Thickness measurement	1. Illustrate flaw detection on chalkboard. 2. Illustrate on chalkboard the measurement of pipe wall thickness. 3. Questions
F. Limitations of ultrasonics 1. Favorably oriented defects 2. Surface condition	1. Compare favorable flaw orientation to radiography. 2. Define the minimum preparation required of parts to be tested. Weld spatter on surface should be removed to ensure proper contact with probe. Small balloon filled with water can be placed between probe and specimen surface to ensure proper contact over irregular surfaces. Oil or grease sometimes used to improve probe-specimen contact. 3. Questions

III. APPLICATION (drill, illustrations, analogies, oral questions or assignment)

Have students illustrate or explain the following:

A. The three methods of pulse echo testing.

B. The detection of a defect by chalkboard sketches using the longitudinal wave, the shear wave, and surface wave techniques.

C. The piezoelectric effect.

D. How discontinuities in a casting can be located by the acoustic impedance method.

E. The sonic method of flow detection; thickness measurement.

F. Advantages and disadvantages of the ultrasonic method of testing.

NOTE: A field trip to a commercial testing lab should be undertaken later to give the students a better understanding of ultrasonic non-destructive testing techniques.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. Define the piezoelectric effect.

B. Draw a sketch of longitudinal wave, shear wave and surface wave propagation modes.

C. What is meant by pulse echo testing?

D. What is acoustical impedance?

E. What are the two major uses of ultrasonic testing?

Check papers and discuss

V. SUMMARY

A. Ultrasonic testing advantage over radiography is that operator can work from only one side of specimen being examined.

B. Disadvantage is intimate contact with specimen requires smooth working surfaces or angle inspections.

C. Area covered in a given time is usually greater than that covered by radiographic methods.

D. Lack of a permanent record, as in radiography, is a disadvantage

E. Wave propagation method of testing is a visual method of inspection employing the use of an oscilloscope.

F. Acoustic impedance method of testing employs the use of sound waves.

The Next Lesson is: Magnetic Particle Testing

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 2
Lesson 2
Time 2 hours

SUBJECT: Magnetic Particle Testing

AIM (or purpose): To develop an understanding of a testing technique other than radiography

TEACHING AIDS: Chalkboard, chalk, and eraser
Horseshoe magnet and cracked specimen

MATERIALS: Oil for wet powder method
Magnetic powders

REFERENCES: Information Sheet #2
Nondestructive Testing Handbook, Volume II, Society for Nondestructive Testing, 1963, Evanston, Illinois
Nondestructive Testing-Magnetic Particle Testing PI-4-3, 1964, General Dynamics-Convair, San Diego, California

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I. PREPARATION (of the learner)
  A. Explain the advantages of the magnetic particle method
    1. Very sensitive to surface defects
    2. Useful for detection of fine fatigue cracks
    3. Requires very little training for most tasks

  B. Show how the method can be used to aid the radiographer
    1. Help to identify film defect indications
    2. Can be used where radiography may not be effective
    3. May be less expensive test for the same quality of inspection

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Magnetic fields 1. Longitudinal fields 2. Circular fields 3. Induced fields	1. Pass out sheet #2, (PP. 7-8 Inst. Guide). 2. Draw chalkboard sketch of the various type fields and how they are produced. 3. Explain how the direction of the energizing current determines the type of magnetic field. 4. Explain how the anticipated defect orientation determine the type of field to be used. 5. The type of current determines the depth of the defect which can be detected. 6. Question the group to emphasize the major points on this topic.
B. Flux leakage 1. At a discontinuity 2. Related to field direction 3. From subsurface defects 4. Methods of detecting	1. Explain the polarity of the flux leakage at a discontinuity. 2. Illustrate why the defect must be of proper shape and orientation to cause leakage. 3. Illustrate by sketching, on chalkboard, the broadening of the flux leakage from subsurface defects. 4. Explain the attraction of magnetic powder to a flux leakage field: a. Particle polarity b. Magnetic attraction 5. Briefly review key points.
C. Magnetic particles 1. Color contrast dry powder 2. Color contrast wet powder 3. Fluorescent wet powders	1. Explain the difference between the three primary types of powders, and the advantages of each type: a. Dry powder has more mobility b. Dry best for subsurface defects c. Wet powders best for fine defects d. Fluorescent powders easier to see when used with ultraviolet light e. Color contrast powders require less expensive equipment

Instructional Topics	Things to Remember to Do or Say
	2. Ask questions
D. Magnetic particle method	1. Demonstrate the magnetic particle method. 2. Select a piece of ferrous material known to contain a discontinuity. 3. Place specimen on table and sprinkle iron powder on surface known to contain discontinuity. 4. Straddle discontinuity with open end of horseshoe magnet. 5. Have students observe how iron powder particles rearrange themselves to the shape of the discontinuity.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Draw typical part shapes on chalkboard or have students to make the drawing on the chalkboard showing typical defects and ask the following questions:
   1. What type of magnetizing field is used to magnetize the part for each type defect?
   2. What type defects cannot be detected by this method?
   3. What type magnetic particle would be best for each defect?

B. Have students sketch the magnetizing of parts to produce:
   1. A longitudinal field
   2. A circular field
   3. An induced field

C. Let students make some applications of magnetic particle flaw detection and observe the pattern of rearrangement of the iron powder particles.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What is a magnetic particle?

B. What causes flux leakage?

C. Why does the direction of the field influence the test results?

D. Draw a sketch of a longitudinal field, a circular field and an induced field indicating the method used to achieve each field.

With the class participating check and discuss the test.

V. SUMMARY

A. Magnetic particle method is a relatively simple, easy to learn, operation.

B. This method locates small cracks that cannot be picked up by radiography.

C. Specimen must be capable of being magnetized.

D. Magnetic particle inspection confined to surface or near-surface discontinuties.

E. This is a relatively inexpensive method of inspection.

The Next Lesson is: Liquid Penetrant Testing

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 2
Lesson 3
Time 1 hour

SUBJECT: Liquid Penetrant Testing

AIM (or purpose): To acquaint the student with testing methods other than radiography

TEACHING AIDS: Chalkboard, chalk, and eraser
Sample defective parts and test blocks

MATERIALS: Liquid penetrant spray can kit

REFERENCES: Information Sheet #2
Nondestructive Testing Handbook, Volume I, Society for Nondestructive Testing, 1963, Evanston, Illinois
Nondestructive Testing - Liquid Penetrant Inspection - PI-4-2, 1964, General Dynamics-Convair, San Diego, California

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I. PREPARATION (of the learner)

Write aim of lesson on chalkboard

A. Explain the advantages of the liquid penetrant method briefly:
   1. Describe liquid penetrant
   2. For inspection of nonmagnetic materials
   3. Detection of surface defects
   4. Relatively inexpensive equipment and materials create economic advantage

B. Tell how the method can be used to aid the radiographer:
   1. Helps to identify film defect indications
   2. Can be used where radiography may not be effective
   3. May be a less expensive test for the same quality of inspection

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Types of penetrants 1. Oil phase 2. Water soluble 3. Color contrast 4. Fluorescent	1. For each type of penetrant describe and explain why used: a. Removal control b. Number of operations involved c. Equipment required d. Ease of viewing 2. Questions
B. Preparation of the part 1. Remove paint, dirt, etc. 2. Degrease	1. Explain and give reasons why: a. Penetrant cannot enter defects b. Penetrant will not displace oil 2. Improper cleaning can cause erroneous answers -- give reasons. 3. Questions
C. Application of penetrant 1. Brushing, spraying, and dipping 2. Time of soak	1. Explain the various methods and application: a. Drag off b. Field inspection vs. laboratory c. Production line testing 2. Manufacturers recommendations should be followed on time of soak since soak time determines entrapment of penetrant. 3. Questions
D. Removal of penetrant 1. Plain water wash 2. Emulsified water wash 3. Solvent removal	1. Water wash for soluble types. 2. Oil phase penetrants require emulsification prior to wash -- explain. 3. Small volume of parts may be solvent cleaned --explain why. 4. Over washing should be avoided. 5. Questions
E. Development 1. Wet developers 2. Dry developers	1. Wet developers best for water phase penetrants on production line testing. 2. Wet developers best suited to use with oil phase penetrants

3. Parts must be dry to use dry developers.
4. Good ventilation required for dry developers.
5. Explain use of developers for withdrawing entrapped penetrant.
6. Questions

F. Inspection
   1. Inspection area
   2. Lighting

1. Refer to information sheet #2 -- explaining why.
2. Inspection should be performed immediately after development.
3. Well lighted area is needed for color contrast penetrant inspections.
4. A darkened area is needed for fluorescent penetrant inspections.
5. Ultra-violet light is needed for viewing fluorescent penetrants.
6. Questions

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Promote the discussion of the limitations of the penetrant method:
   1. Will the method detect subsurface defects?
   2. What effect does oil have on the entrapment of a penetrant?
   3. Would the technique be useful for detecting leaks in vessels, etc?

B. Request a listing of the steps of the process in their proper order.

C. Discuss the advantages of the fluorescent method over the color contrast method.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. List the steps of the penetrant process in the proper order.

B. List three examples of poor practice which will cause false results.

C. Why do the listed practices cause false results?

D. Why is the penetrant method more effective on shallow surface defects than radiography?

Check papers and discuss.

V. SUMMARY

A. **Liquid penetrants can be used to inspect non-magnetic materials.**

B. **Specimen must first be thoroughly cleaned and de-greased.**

C. **Liquid penetrant method is limited to detecting surface defects.**

The Next Lesson is: **Inspection of a Defective Part using the Liquid Penetrant Method**

INSTRUCTOR'S LESSON PLAN
Manipulative Skills

Unit 2
Lesson 4
Time 2 hours

JOB (or operation): Inspect a defective part using the liquid penetrant method

AIM (or purpose): To develop skill in the technique of liquid penetrant inspection

MATERIALS: Paper Towels
Liquid Penetrant Kit

TEACHING AIDS: Chalkboard, chalk and eraser
Sample defective parts and test blocks
Manufacturers instruction sheets

REFERENCES: Nondestructive Testing Handbook, Volume I, Society for Nondestructive Testing, 1963, Evanston, Illinois
Nondestructive Testing - Liquid Penetrant Inspection PI-4-2, 1964, General Dynamics-Convair, San Diego, California

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I. PREPARATION (of the learner)
   A. Write AIM of lesson on chalkboard.

   B. Explain the importance of being able to perform a liquid penetrant inspection:
      1. A good technician has a basic knowledge of testing methods
      2. The test can be useful in the interpretation of radiographs
      3. The method may be more useful than radiography for certain applications

II. PRESENTATION (of the skills)

Operations or Steps	Key Points (things to remember to do or say)
	Proceed slowly & carefully explaining each step -- questioning as demonstration develops Give reasons whenever necessary.
A. Demonstrate:	
1. Preparation of part	1. Remove all paint, dirt, etc, by brushing, chemicals or other suitable methods. 2. Degrease part with spray can cleaner.
2. Place part on inspection table	1. Turn area to be inspected upward 2. Place on paper or cloth to protect table.
3. Apply penetrant	1. Direct spray nozzle toward inspection area. 2. Hold about 12" from part to get best coverage. 3. Press valve to release penetrant 4. Spray to cover entire inspection area. 5. Do not waste penetrant by spraying until dripping 6. Allow to soak for time recommended by supplier.
4. Remove penetrant	1. Wipe off surface penetrant with cloth. 2. Wet cloth or towel with cleaner/remover from spray can. 3. Wipe off remaining excess penetrant with dampened cloth. 4. Continue to clean until only a trace of penetrant is visible. 5. Caution: overcleaning by direct spraying may remove all penetrant from very shallow or wide defects
5. Apply developer	1. Direct developer nozzle toward the inspection area.

2. Hold nozzle 12" to 18" from the part to achieve best action of developer.
3. Spray lightly by pressing spray can valve.
4. Inspection area should just be damp while applying developer.
5. Caution: over wetting of the inspection surface will cause running of the indications and hinder interpretation of results.

6. Inspection

1. Allow adequate time for developer to stand. Check for recommended time.
2. Observe any indication of stains which indicate a defect.

NOTE: BEFORE GOING FURTHER MAKE SURE OF UNDERSTANDING BY ASKING QUESTIONS

III. APPLICATION (practice by learner under close supervision)

A. Supervise groups of students in the performance of a liquid penetrant inspection.

B. Discuss the factors which can cause poor results after student has made liquid penetrant inspection.

C. Instruct students to tell what they did and why.

IV. TEST (performance of skill to acceptable standards)

A. Assign students to perform a complete penetrant inspection. Give each student close supervision during test.

B. Discuss and comment on results observed.

V. SUMMARY

A. Preparation of test specimen must be thorough to insure best results.
B. Use of the penetrant materials in the proper sequence is mandatory.
C. Each step must be timed according to manufacturers instructions.

The Next Lesson is: Visiting a Commercial Nondestructive Testing Laboratory.

INSTRUCTOR'S LESSON PLAN
Manipulative Skills

NOTE TO INSTRUCTOR: All field trips must be carefully planned well in advance to make sure students will be able to observe the items given in Step I of this lesson.

Unit 2
Lesson 5
Time 6 hours
(includes travel)

JOB (or operation): Visiting Commercial Nondestructive Testing Laboratory

AIM (or purpose): Develop a better understanding of the various inspection techniques employed by industry for control of material quality

MATERIALS: Film badges
Dosimeters
Safety glasses
Hard hats

TEACHING AIDS: Chalkboard
Chalk
Eraser

I. PREPARATION (of the learner)
   A. Write aim on chalkboard.

   B. Ask students to observe the following:
      1. The different types of inspection equipment and processes
      2. The internal quality control measures to insure reliable inspection results
      3. The methods used to identify the customers materials
      4. Preparation of materials prior to inspection
      5. Preparation of technique cards and work logs
      6. Marking of parts for disposition
      7. Preparation of reports and certifications
      8. Radiation safety devices
      9. A test will be given to check the results of this field trip

II. PRESENTATION (of the skills)

Operations or Steps	Key Points (things to remember to do or say)
A. Stress safety procedures which are to be followed in the laboratory	1. Select a commercial nondestructive testing laboratory which offers a a complete complement of testing processes.
B. Issue equipment, goggles, hard hats, etc., before entering laboratory or as instructed by company officials	2 Cover all aspects of safety. 3. Point out the need for gentlemanly behaviour and the fact that we are visitors.

III. APPLICATION (practice by learner under close supervision)

A. After returning from the trip, ask the students to discuss and explain:

1. The different processes and techniques observed in use by the laboratory
2. Established internal controls to insure a quality inspection
3. Methods of maintaining records of techniques employed in various tests
4. Safety devices used in maintaining radiation survelliance

B. Discuss any unusual situations observed during the tour of the laboratory.

IV. TEST (performance of skill to acceptable standards)

NOTE: WRITTEN TEST

A. Name the different types of nondestructive testing methods you observed in this laboratory.

B. Describe their safety equipment and procedures.

C. Describe some of the records that must be kept and also furnished the client.

D. What is meant by "Internal Controls" to insure a quality inspection?

Discuss results of test

V. SUMMARY

A. Safety precautions.

B. Various types of tests and inspections.

C. Need for records.

D. Conduct on tours and plant visitations.

The Next Lesson is: Professional Ethics for the Industrial Radiographer

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 3
Lesson 1
Time 2 hours

SUBJECT: Professional Ethics for the Industrial Radiographer

AIM (or purpose): To develop an appreciation of the responsibilities of a Radiographer and situations which may arise in the span of his career

NOTE TO TEACHER:
Secure sufficient number of copies of AEC or State regulations in advance of this class to hand out at this time

TEACHING AIDS: Chalkboard, chalk, and eraser
Copy of AEC or State regulations

REFERENCES: Welding Inspection Manual D-1, D-46, Page 42, FOREWORD "Description of an Inspector" American Welding Society 33 WEST 39th St., New York, N. Y.

AEC or State regulations (Information Sheet #3)

I. PREPARATION (of the learner)

A. Write aim of lesson on chalkboard.

B. Ask the following questions:
   1. How can a radiographer augment his salary?
   2. What are the normal results of unethical business practices and conduct?
   3. Express how you feel about such practices

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The inspector	1. Explain that the radiographer may not always be the inspector. 2. Explain also that the inspector is generally not the evaluator. 3. Define the job of the inspector as: The interpretation of the results of an inspection of parts or an assembly and the report of this inspection to the controlling authority. 4. Questions
B. The responsibility of the inspector-radiographer	1. Explain to the prospective inspector-radiographer his role in: a. Ensuring product reliability b. Prevention of accidents and loss of life c. Securing a profit for the employer d. Maintenance of radiographer equipment e. Reporting deficiencies in equipment and personnel under his supervision 2. Questions
C. Short cuts which lead to professional degradation	1. Point to the tendency to produce inferior quality as the working conditions worsen. 2. Explain the hazard and consequences of the following unethical practices: a. Incorrect penetrameters b. Wrong placement of penetrameters c. Incorrect film types d. Incorrect film-focal distance e. Substitution of satisfactory film for film from areas of inferior quality 3. Explain the moral and legal problems caused by irradiation of persons not under a health control program.

    a. You and your company could be sued
    b. Your AEC License could be revoked
    c. Criminal charges could be filed against you and your company
    d. You have a moral responsibility to protect those who are in your work area
4. Questions

D. The industrial spy

1. Point out the tendency of some companies to employ means of gaining information from competitors.
2. Illustrate a number of job assignments where a radiographer has access to condfidential information:
    a. Defense plant work
    b. Research work on space programs
    c. Work on parts for which a patent has been applied
3. Warn the student of the hazard if discussing his work with people outside of his job responsibilities.
4. Questions

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Ask the students for an opinion of their responsibilities to an employer observing unusual attitudes as this will indicate individuals who may need closer supervision and guidance.

B. Invite students to explain or discuss the legal consequences for accepting gratuities for the falsification of test records.

C. Suggest students explain and discuss the role of the inspector in:
    a. Making a profit for the company
    b. Maintenance of equipment
    c. Ensuring safety of company and customer personnel

D. Assign students to discuss the job of an inspector.

IV. TEST (final check on students' comprehension of material presented)

NOTE: WRITTEN TEST

A. What are the possible consequences of accepting favors or money for falsifying records?

B. What is the job of the inspector?

C. Name three hazards of using unethical radiographic short cuts.

D. What possible monetary loss or consequence could arise from the unnecessary exposure of others to radiation?

E. What is the best way to avoid revealing industrial secrets?

Check and discuss

V. SUMMARY

A. Unethical reporting methods and practice can destroy the value of product inspections.

B. Improper inspection practice can create and propogate hazardous working conditions.

C. Poor inspection practices can be considered a form of sabotage.

D. How federal laws control the possession, use and handling of radioisotopes in industry.

The Next Lesson is: Radiation detection instruments

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 4
Lesson 1
Time 2 hours

SUBJECT: Radiation Detection Instruments

AIM (or purpose): To develop an understanding of the use of instruments for detection and measuring ionizing radiation

TEACHING AIDS: Film Strip: Civil Defense Radiological Instruments, 35 mm Office of Civil Defense, Department of Defense, (Complete with lecture narrative from Radiological monitoring for Instructors course; RMI, or Exhibit-A of Appendix)
35mm film slide projector and screen
Dosimeters, dosimeter charge, and survey meters

REFERENCES: Maintenance manuals for instruments
Radiation Safety in Industrial Radiography with Radioisotopes, P. M. Frazier, C. R. Buchanan, B. W. Morgan, Bulletin AECU 2967, U. S. Atomic Energy Commission, Washington, D. C.

I. PREPARATION (of the learner)

A. State the subject of this lesson and briefly explain why radiographers must be familiar with radiation detection instruments.

B. Introduce the film and explain briefly the important items it covers including the following:

1. Different types of instruments for detecting ionizing radiation
2. Purpose of each type of detecting instrument
3. Similarities in the ability of each to detect ionizing radiation
4. The limitations of each type of detecting instrument
5. The basic difference between a dosimeter and a survey meter
6. The comparison of total dose vs dose rate
7. The definitions of the following: Roentgen, rad, and rem and how they apply to radiation safety
8. Abbreviations of certain often used terms

C. Advise group a test will be given.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Show the film strip in three parts	NOTE: Present the narrative in three (3) parts as furnished with the film strip.
	NOTE: Ask for questions or ask questions during the showing of each of the three parts.
Part I:	Part I: Dosimeters and dosimeter charges
Part II:	Part II: Geiger Muller-type survey meters
Part III:	Part III: Ionization chamber-type survey meters

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Review the following points of information presented in the film:

1. Similarity of the various types of radiation detection instruments
2. Difference between a geiger counter and an ionization chamber
3. Meaning of dose rate
4. Meaning of roentgen, rad, and rem
5. Desirable characteristics of detection instruments
6. Undesirable characteristics of different types of detecting instruments
7. Care and maintenance of detecting instruments

B. Call on individuals in the class to give the abbrevations for roentgens, roentgens per hour, milliroentgens per hour.

C. Point out the basic difference between a dosimeter and a survey meter as was illustrated in the film strip.

IV. TEST (final check on students' comprehension of material presented)

A. Give a written test -- (The following questions are suggested)
   1. List four desirable characteristics of survey meters.
   2. What is the phenomenon on which the detection of radiation is based in the construction of gamma ray detection and measuring instruments ?
   3. What are the two most popular types of enclosed gas volume rate-measuring instruments ?
   4. Define dose and dose rate.
   5. Explain the operation of an ionization chamber. Use a sketch if necessary.
   6. Draw a sketch of the ionization chamber and electrometer suspension of the pocket dosimeter. Label the parts.

B. After the class has completed the test, state the correct answers to each question with the students assisting.

The Next Lesson is: The Film Badge

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 4
Lesson 2
Time 1 hour

SUBJECT: The Film Badge

AIM (or purpose): To thoroughly acquaint the student with the function and construction of an industrial film badge

TEACHING AIDS: Film badge holder and film badge
Cut-away of film badge and holder

I. PREPARATION (of the learner)

A. Write aim on chalkboard.

B. Explain the importance of the film badge.
   1. Give an account of an actual incident such as the following: A filme badge processing service company wired a customer that one of its film badges indicated an exposure to 5,000 millirem of gamma ro x radiation. An investigation revealed the employee had lost his film badge temporarily while making radiographic exposures and the film badge was later found a few inches from the exposure device. This indicated the film badge, but not the wearer, was exposed to 5,000 m/rem.
   2. Indicate that it used to control the radiographers radiation exposure and will determine if the radiographer has exceeded his safe operating dosage.
   3. Point out that control and monitoring of dosage is essential to the continued health and safety of the radiographer.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Purpose of film badge	1. Display cut away badge and film envelopes so that all may see construction. 2. Explain how the badge is used to measure accumulative dosage.

II. PRESENTATION (continued)

Instructional Topics	Things to Remember to Do or Say
	3. Point out reason why film badge is used in addition to the dosimeter. 4. Indicate that the badges are for permanent record.
B. Types of radiation detected	1. List the two basic types of radiation detected: beta and gamma. 2. Explain how these are recorded on one film by use of filters, filter density and thickness filters out beta particles.
C. Construction of film badges and film badge holders	1. Sketch the construction of the badge and holder, and display actual items. 2. Stress that the purpose of the cadmium and copper strips in the holder-filters out beta particles in filtered area leaving only an indication of gamma radiation. 3. Define the function of the film badge holder case; In addition to filtering it provents damage to films, also provides convenient carrying case.
D. Wearing of film badges	1. Give reasons why badges should be worn: a. Badges should be worn on the body b. Badges should be worn at all times while performing radiographic operations c. By only one person
E. Care of film badges	1. Point out why: a. Badges must not be placed near heat. b. Film badges must be stored away from radiation.

    c. Badges must be in holder when worn.
    d. Badges must be kept dry.

F. Control badge

1. Explain purpose of control badge:
    a. During shipment to and from customer and while radiographer is not using badge, all badges are stored with control badge.
    b. If control badge indicates 50 m/rem when checked, subtract same amount from individual users dose.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Have all students sketch a cross section of the typical film badge holder with filters.

B. Ask students to explain the purpose of the filters.

C. Ask students to list three actions which could damage the film badge.

D. Have students explain all the rules for wearing film badges.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What are three mandatory rules regarding the wearing of film badges?

B. Why does a film badge holder have metal strips attached inside?

C. Why is the film badge worn in addition to the dosimeter?

D. What are the three types of radiation recorded by the film badge?

E. Does the film badge record total dose or dose rate? Explain in detail?

Check and discuss when all tests are completed.

V. SUMMARY

A. Film badges advantage is that a permanent record of total accumulated exposure is obtained.

B. Badge can indirectly differentiate between beta and gamma radiation.

C. Film badge and dosimeter readings compliment each other.

The Next Lesson is: Use of Pocket Dosimeters

INSTRUCTOR'S LESSON PLAN
Manipulative Skills

Unit 4
Lesson 3
Time 2 hours

JOB (or operation): Use of Pocket Dosimeters

AIM (or purpose): To develop skill in the use, and maintenance of pocket dosimeters and chargers

TEACHING AIDS: Pocket dosimeters
Dosimeter charger
Small source of ionizing gamma radiation such as 5 mc Co60 sources used in civil defense classes

REFERENCES: Manufacturers operation and maintenance manuals for dosimeter and charger

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I. PREPARATION (of the learner)

A. Show the class a pocket dosimeter and explain its importance to a radiographer.

B. Point out advantages of the dosimeter over the film badge.

C. Emphasize the importance of proper maintenance of pocket dosimeter and charger.

II. PRESENTATION (of the skills)

Operations or Steps	Key Points (things to remember to do or say)
A. Reading the dosimeter	Position students so they can see and hear. 1. (DEMONSTRATE) and point out the various parts of a dosimeter and charger. 2. Point out that the eyepiece should be held about 1/2" from the eye.

3. Call attention to the strong light or use light on charger.
4. CAUTION not to press the dosimeter to charger position when using charger as this would cause the reading to be altered.
5. Emphasize that the zero mark should be to the left of the field of vision.
6. Note that the dosimeter need not be set to exactly zero at the beginning of the exposure period.
7. Explain that the dosage is determined by subtracting the first reading from the last reading in the exposure period.

B. Charging of dosimeters
   1. Place charger on table
   2. Connect dosimeter to charger
   3. Adjust the dosimeter

Demonstrate and explain each step

1. Place at convenient height for ease of reading of dosimeter. Remove dust cover from charging receptacle.
2. Remove dust cover from dosimeter. Insert contact into charging receptacle.
3. Place eye about 1/2" from the eyepiece of the dosimeter.
4. Depress the dosimeter to the bottom of the receptacle.
5. Rotate the adjust knob on the charger until the dosimeter reads near zero.
6. Release pressure on dosimeter until charger disengages.
7. Read dosimeter using internal light to ascertain if charging is correct.
8. Emphasize importance of reading scale in horizontal positions.

II. PRESENTATION (continued)

Operations or Steps	Key Points (things to remember to do or say)
C. Dosimeter charger adjustments	Demonstrate and explain. 1. If dosimeter will not zero: a. Replace battery in charger b. Polish battery contacts with crocus cloth 2. If replacement battery is not available, try removing the light bulb inside charger. 3. Explain why 4. If bulb is burned out, replace with the spare bulb located inside the case.

III. APPLICATION (practice by learner under close supervision)

A. Have students demonstrate ability to read and charge dosimeter.

B. Let students reset dosimeters to read exactly 100 mr. Ask students to turn dosimeter 180 degrees so that the reticle or scale is up-side-down, and have them read dosimeter in the inverted position.

Repeat readings obtained at 90 degrees and at 180 degrees from horizontal. Compare readings with horizontal reading.

IV. TEST (performance of skill to acceptable standards)

A. Ask one or more students to charge dosimeters to near zero and let other class members check for correct procedure.

B. Have students place their dosimeters on the rim of a 2 foot radius circle. Place a 5 MC cobalt 60 source in the exact center of the circle and let each student calculate the period of time to produce a dosage of from 100 to 150 mr. at the circle. Remove all dosimeters at the same time.

C. Have students read, record, and recharge his dosimeter.

D. Compare and discuss the results of each students efforts.

The Next Lesson is: How to Use a Survey

INSTRUCTOR'S LESSON PLAN
Manipulative Skills

Unit 4
Lesson 4
Time 2 hours

JOB (or operation): How to use a Survey Meter

AIM (or purpose): To develop adeptness in the operation of beta-gamma survey meters

TOOLS AND EQUIPMENT: Several beta-gamma survey meters
Radioactive gamma source

REFERENCES: Manufacturers operation and maintenance manuals

I. PREPARATION (of the learner)

A. Explain the importance of the proper use of survey meters. Pointing out that it is the most valuable piece of safety equipment in the radiographers possession. It indicates the presence of a radiation field and immediately indicates its intensity.

B. Indicate that in almost every case radiographic accidents could have been avoided if the survey meters had been used properly.

C. Relate story or personal experience along this line such as: A radiographer was making several exposures using a gamma exposure device as illustrated on the chalkboard. This device enabled the radiographer to crank the source capsule into a flexible tube. At the end of each exposure he was supposed to crank the capsule back into the device and then check the surface of the device with his survey meter to make certain the capsule was safely back in the storage device.

After making several routine exposures he stopped checking the device with his survey meter after each exposure.

At the completion of his assignment he noticed that the survey meter indicated the source was not in the storage device. A quick check with his survey meter located the capsule at the far end of the flexible source tube.

For quite some time he had been cranking the source out when he should have been cranking it in. As a result he had been exposing himself to a large amount of ionizing radiation and was not making any radiographs. A quick check with the survey meter before and after each exposure would have prevented this accident.

II. PRESENTATION (of the skills)

Operations or Steps	Key Points (things to remember to do or say)
NOTE: Encourage students to ask questions during Demonstration. Position students so they can see and hear.	
A. Pick up survey meter	1. Grasp meter by handle. 2. Point chamber end away from body, explaining why.
B. Turn instrument switch to on position	1. Turn selector switch to zero position. 2. Allow the instrument to warm up at least two minutes, pointing out why.
C. Zero calibrate	1. Turn zero knob until needle reads zero on meter. 2. Observe needle for drift or erratic action. 3. Repeat zero step after waiting a short period if needle tends to drift.
D. Range selection	1. Check the zero reading on each scale as the switch is moved to each position. NOTE: The zero should not shift when the meter is not in a radiation field. 2. Turn selector switch to the position for the required measurement of radiation.
E. AEC range requirements	Explain that meter must be capable of indicating ionizing radiation intensity from 2 mr/hr to 1 r /hr.

III. APPLICATION (practice by learner under close supervision)

A. Request that each student perform the normal operation of zeroing and checkout of the survey meter.

B. Draw meter readings and range switch position on chalkboard and have students state dose rates indicated.

C. Question group in the areas of what, how and why.

IV. TEST (performance of skill to acceptable standards)

NOTE: Written Test

A. What is the purpose of the adjustable rheostat knob?

B. The survey meter ____________ and measures _______ ________.

C. A survey does not measure ___________ dose.

D. Survey meter ranges can be ________ to indicate __________ per hour as well as ____________ per hour.

E. An AEC approved survey meter for use in radiography must have a range of __________ mr/hr or lower to __________ r/hr or higher.

V. SUMMARY

A. Survey meters or rate meters give a quick indication of the presence of a radiation field.

B. Rate meters also indicate the dose rate of a radiation field.

C. Rate meters cannot indicate the total accumulated dose unless the radiation field is constant.

The Next Lesson is: Practical Procedures for Measurement

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 4
Lesson 5
Time 2 hours

SUBJECT: "Practical Procedures for Measurement"

AIM (or purpose): To develop an understanding of the supporting theory of radiation detection instruments used in industrial radiography

TEACHING AIDS: Film: PRACTICAL PROCEDURES FOR MEASUREMENT, 48 mins., 16 mm, sound, U.S. Atomic Energy Commission

EQUIPMENT: Film projector and screen

I. PREPARATION (of the learner)

A. In order to achieve the maximum benefit from radiation detecting and measuring devices a radiographer must be familiar with the operating characteristics of the equipment. A thorough knowledge of the equipment in which the radiographer has entrusted his life can only be termed as good common sense.

B. LOOK FOR THE FOLLOWING POINTS IN THE FILM:
The avalanche effect in a geiger tube.
Fluorescent effect in a scintillator.
Steady flow of current generated in an ionization chamber.
The operating ranges of the three types of instruments and their individual characteristics.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. "Practical Procedures for Measurement." First part, Principles of Radiation Detection	1. Show film, rerun if necessary stopping film to clarify points as needed.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Request students to show by chalkboard sketches or with pencil and paper the range of voltage operation of each of the three type detectors.

B. Have them review and discuss the characteristics of the three types of detectors.

C. Discuss the formation of secondary ion pairs and the phenomenon called an "ion avalanche".

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. List in increasing order of operating voltage the three types of detection instruments shown in the film.

B. Outline the operating characteristics of each type instrument.

C. What happens in a detection chamber when a gamma ray passes through?

D. What are secondary ions?

E. What is an ion avalanche?

Check papers and discuss

V. SUMMARY

A. The need for radiation detection and measurements, the principles and the use of various types of instrumentation.

B. Emphasis on the Geiger-Muller tube

C. Absolute and comparative activity measurements.

The Next Lesson is: Radiation

V. SUMMARY

A. Safety Precautions

B. Various types of tests and inspections

C. Need for records

D. Conduct on tours and plant visitations

The Next Lesson is: Professional Ethics for the Industrial Radiographer

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 4
Lesson 6
Time 1 hour

SUBJECT: Radiation

AIM (or purpose): To develop familiarization with the methods of monitoring and the control of penetrating radiation

TEACHING AIDS: Film: Living with Radiation, 28 mins., 16mm, sound, U.S. Atomic Energy Commission

EQUIPMENT: Film, projector and screen

I. PREPARATION (of the learner)

A. Introduce subject and aim of lesson - write it on chalkboard.

B. Look for the following points while viewing the film!
   1. Continuous employment of survey meters by the atomic workers while conducting work with radioactive materials.
   2. Types of monitoring devices used at the facility in addition to survey meters.
   3. Methods used in disposal of unwanted radioactive materials.
   4. Heavy shielded chambers used to make precision measurements of weak source strengths.

C. The points given above will assist the learner to better understand the various methods of monitoring and controlling penetrating radiation.

D. Advise group a test will be given.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
"Living with Radiation"	Show film, rerun if necessary stopping film to clarify situations as necessary.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments) Discuss the film - Emphasizing these points:

A. Use of safety devices and monitoring equipment used by the atomic workers.

B. Monitoring devices used by atomic workers but seldom employed in industrial radiography.

C. The safety record of the facility shown in the film relating this to the safety devices used by the facility.

D. Waste disposal procedures shown for the disposal of radiographic sources.

E. The purpose of the heavy shielding used in the construction of the counting devices. Relate this to instruments used in wipe testing.

F. Rerun film again if necessary for understanding of certain situations or of certain items that still may not be clear.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Oral Quiz

A. Name at least four different detection devices used by the atomic workers in the film.

B. Why is it necessary to have controlled disposal methods for radioactive materials?

C. What is the purpose of the heavy shielding used with the counters shown in the film?

D. Why do the atomic workers always use the survey meter when working with radioactive materials?

V. SUMMARY

A. Separation-distance factor

B. Storage and/or disposal of radioactive wastes

C. Protection of populations, water, crops, and livestock by air and enviromental monitoring.

D. Protection of workers through use of film badges, radiation counters, shielding, remove-control devices, decontamination procedures and biochemical studies.

E. The various types of detection instruments

The Next Lesson is: Algebriac Expressions

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 5
Lesson 1
Time 1.5 hours

SUBJECT: Algebraic Expressions

AIM (or purpose): To develop skill in the use of algebraic equations

REFERENCES: Brief College Algebra, W. L. Hart, 1947, D. C. Heath and Co., Boston, Mass.
Industrial X-ray Handbook, Allan Lytel, 1962, H. W. Sams, Indianapolis, Ind.
Information Sheet #4

I. PREPARATION (of the learner)

A. Using chalkboard list the subject of lesson explaining why it is essential to have a working knowledge of algebraic expressions.

B. List several algebraic formulas on the board gauging their complexity to the contemplated proficiency level of the group in attendance.

C. Upon determining the lowest level of understanding present, proceed with the presentation, keeping before the group good and sufficient reason for wanting to know.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The fundamental operations	Define and illustrate on the chalkboard:
a. Addition	1. Addition: Combining two or more numbers so as to obtain a number called a sum.
b. Subtraction	2. Subtraction: The act of taking one number or quantity from another.
c. Multiplication	3. Multiplication: The process of adding a given number or quantity a certain number of times by a briefer computation.
d. Division	

	4. Division: The process of determining how many multiples of one number are contained in another.
B. Numbers: a. Explicit b. Literal	Define the explicit and literal numbers: 1. Explicit number-absolute value of a signed number. 2. Literal number-letter that stands for a number.
C. Law of	List the rules on the chalkboard and explain: 1. When multiplying or dividing, the answer will have a plus sign if both numbers have the same sign and a negative sign if the operators are of opposite sign. 2. When adding like signs, the sum has the sign of the operators. When adding unlike signs, the sum has the sign of the operator with the greatest absolute value. 3. To subtract, change the sign of the operator and add.
D. Principles of fractions	State and illustrate on the chalkboard; 1. The value of the fraction is not changed if both the numerator and denominator are multiplied or divided by the same number, not zero 2. The product of two fractions is the product of the numerators divided by the same number, not zero. 3. To divide a fraction by another invert the divisor and multiply. 4. To multiply a fraction by a number, multiply the numerator by the number.

5. To divide a fraction by a number, multiply the denominator by the number.

E. The equation

1. List the following definitions:
   a. An equation is a statement that two members of an expression are equal.
   b. A solution is a set of values that satisfy the equation. Illustrate.
2. Illustrate the rules of equivalent equations:
   a. Add and subtract the same value from both sides.
   b. Multiply both sides by the same value.
   c. Cancel equal terms on both sides.
   d. Transpose terms from one side to the other by changing signs.

F. Equations

$$\frac{EP \times D^2}{S} = T$$

Explain step by step use of equation using the following information work problem: Explain each step what is being done and why:

1. A client requests a gamma radiograph be made of a steel casting 4"x6"x 1/2" thick. Relative film density should be 1.5, film should be Kodak type AA, film-focal distance should be 12" and an Iridium 192 gamma source should be used. You have a 10 curie (10,000 millicurie) source. What should your exposure time be?
   Ans: Exposure factor - 70 (from chart) film-focal distance squared = 12x12=144" Gamma source strength= 10,000MC (10 curies) = $\frac{70 \times 144}{10,000}$ = 1.08 minutes exposure time.

Instructor using a chalkboard, should have students tell what to do, how to do it, and why it is being done in solving the following problems (2) and (3):

2. Solve for exposure time if EF = 100 D = 10" and S = 5 curies.

$$\frac{EF x D^2}{5} = T$$

3. Work step by step on chalkboard. If radiation intensity at one foot is 500 MR/HR; what is the intensity at five feet?

$$\frac{I_1}{I_2} = \frac{D_2^2}{D_1^2}$$

$$\frac{500}{X} = \frac{25}{1}$$

$$\frac{500}{25} = \frac{X}{1}$$

$$X = 20$$

Ans: 20 mr/hr at 5 feet

G. Work step by step on chalkboard: If it took 100 milliamp seconds (MAS) to produce an x-ray radiograph @ 1 foot film-focal distance how many film-focal distance MAS would be required if the film-focal distance was lengthened to 2 feet?

$$\frac{MAS\ 1}{MAS\ 2} = \frac{D_1^2}{D_2^2}$$

$$\frac{100}{X} = \frac{1}{4}$$

$$\frac{100}{x} = \frac{X}{4}$$

$$X = 400$$

Ans: 400 MAS @ 2 feet

H. Work step by step on chalkboard: What is the exposure factor if a radiograph was made in 10 minutes with 5,000 millicuries of Iridium 192 at a focal distance of 8 feet?

$$\frac{TS}{D^2} = EF$$

$$\frac{10 \times 5000}{64} = \frac{50,000}{64} = 781$$

Ans: EF = 781

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Require students to solve for a given value in terms of all others using the equations for: The Time-Distance rule, the Ma-Time rule, the Ma-Distance rules, and the inverse square law. Supervise very closely until all students have mastered the technique of handling algebraic expressions.

B. Have them list the laws governing signs in the operations of addition, subtraction, multiplication, and division.

C. Ask for a listing of the rules governing operations to produce equivalent equations.

D. Have class solve the following problems and explain.
1. Intensity at 2 feet is 600 mr/hr. What is it @ six feet? @ 1.5 ft?
2. T = 2 minutes, S = 500 mc, D = 4 feet, what is EF?
3. T_1 = 2 minutes, D_1 = 4 minutes, D_2 = 1 foot what will T_2 be?
4. EF = 100, D = 2 feet, S = 2000 mc. What is T in minutes?

Work all problems on the chalkboard allowing class to discover and correct any errors as they may develop.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. Olve for D^2: $\frac{I}{I_o} = \frac{D^2}{D^2}$

B. Solve for Ma_1: $\frac{D_2^2}{D_1^2} = \frac{Ma_1 \ S_1}{Ma_2 \ S_2}$

C. If Ma_1 = 5 ma
S_1 = 60 sec.
Ma_2 = 10 ma
What is the time of S_2 if $Ma_1 \ S_1 = Ma_2 \ S_2$

D. Solve for the new time if:
T_1 = 10 sec.
D_1 = 24 inches
D_2 = 48 inches

and

$$\frac{T_2}{T_1} = \frac{D_2^2}{D_1^2}$$

Check and discuss

V. SUMMARY

A. An understanding of the use of algebraic expressions, formulas, and equations is essential in radiography.

B. Mathematical law of signs must be understood.

C. Formulas and equations tend to speed up and simplify most radiographic mathematical problems.

The Next Lesson is: The Inverse Square Law

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 5
Lesson 2
Time 1.5 hours

SUBJECT: The Inverse Square Law

AIM (or purpose): To develop an understanding of the meaning, manipulation, and use of the mathematical relationship as used in radiography calculations

REFERENCES: Radiography in Modern Industry, Eastman Kodak Co., 1958, Rochester, N. Y.
Nondestructive Testing Handbook, Society for Nondestructive Testing, 1963, Evanston, Illinois
Information Sheet #4 (see appendix)

I. PREPARATION (of the learner)

A. Find out by oral questions what knowledge the class has about the inverse square law.

B. Point out that all exposure calculations in radiography are based on the inverse square law and that the radiographer will never fully understand his trade until he has mastered its use in making necessary calculations.

C. Indicate that the inverse square law is used to calculate the distance required to be safe from harmful radiation.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The inverse square law-define and explain	1. The inverse square law is: a. The basic mathematicsl relationship between intensity and distance b. The most frequently used relationship in industrial radiography

	c. The basis of all exposure calculations
B. The mathematical formula	1. Write the inverse square law in mathematical terms on the chalkboard. 2. Explain the symbols in the inverse square law equation. 3. Transpose the equation to all forms-distance, time, intensity.
C. Visual schematic illustration	Draw on chalkboard a geometric sketch of the inverse square law relationship and discuss with the class.
D. Application of inverse square law	Work the following problems on chalkboard step by step. Explain each step encouraging students to ask questions: a. Exposure time is 3 minutes at 1 foot. What is exposure time at 3 feet? b. Intensity at 1 foot is 500 mr/hr. What is intensity at 2 feet? c. Intensity at 5 feet is 200 mr/hr. At what distance is intensity 2 mr/hr?

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Ask the students to recite a word statement of the inverse square law.

B. Ask the students to define the inverse square law by an example.

C. Place the inverse square law on the chalkboard in one form and ask the students to transpose to all the other possible forms.

D. Give the students a set of conditions for each of the following cases: Calculate from the given data:
  1. A value of I_o
  2. A value of D_o
  3. A value of D
  4. A value of I

IV. TEST (final check on students' comprehension of material presented)

A. Write the inverse square law in any form.
B. Transpose to all other forms. Show each step.
C. Give three examples for use of the inverse square law.
D. Given the following information, solve each problem:
Cobalt 60 yields 14,500 mr/hr/curie at 1 foot
Iridium 192 yields 5,900 mr/hr/curie at 1 foot

  1. What is the distance where the intensity of radiation from 5 curies of Cobalt 60 is 20 mr/hr?
  2. At 20 feet from a source of Iridium 192 the radiation intensity is 250 mr/hr. How many curies of Iridium is present?

Check the answers with the class and discuss -- correcting all errors.

The Next Lesson is: The Square Root

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 5
Lesson 3
Time 2 hours

SUBJECT: The Square Root

AIM (or purpose): To develop skill and understanding in solving problems involving square root as applied to radiography work

REFERENCES: Information Sheet #5

I. PREPARATION (of the learner)

A. Explain briefly why it is important for a radiographer to be able to figure square root.

B. Give practical situations where this type calculation is needed. For example: To solve problems involving safe working distances and distance shielding problems.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The square root	Using simple examples explain the meaning of square root.
B. The long division-estimate method of determination	1. Illustrate on the chalkboard the calculation of the square root of the number 2 using the following procedure: a. Write the number as a non-terminating decimal; i. e., 2.000000. b. Group the digits to the right and left of the decimal point in pairs; i. e., 02. 00 00 00. c. Construct the square root sign over the number and place the decimal point just above the decimal point in the number.

d. Estimate the square of the first pair of numbers. Use the whole number which is nearest but just less than the first pair.
e. Write this number above the first pair and the square of the number below the pair.
f. Subtract the squared number from the first pair and draw down the next pair as in long division; i. e., 1+00 = 100.
g. Double the value of the number above the first pair (1) and add a zero to the value; i. e., 2 (1) - 2, 2+0 = 20.
h. Divide this number (20) into the number obtained in step "f". Add the quotient to the number in step "g" and multiply by the quotient. If the product is greater than the value of step "f" reduce the quotient number by one and repeat until the product is just less than step "f"; (20+4) times 4=96.
i. Write this number above the second pair.
j. Double the value of the number above the radical sign and add a zero 2(14) = 28+0 = 280. Repeat steps "h" and "i".
k. Continue the process to obtain the accuracy desired. Ask questions, and have students solve problems.

2. Work several problems on the chalkboard with the class assisting.

C. The estimate- average technique

Illustrate on the chalkboard the calculation of the square root of the number 10.

a. Estimate the value of the root of 10. (Use the figure 3).
b. Divide 10 by 3 for an approximate answer of 3.3.

c. Add 3 and 3.3; divide the result by 2.

d. Divide 10 by 3.15 from step "c". Ans. 3.17.

e. Add 3.15 and 3.17; divide the result by 2.

f. Continue the process as above until the desired accuracy is obtained.

Have students solve problems using this technique.

D. Use of square root tables

Hand out and explain the use of tables.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Have students solve the following problems using the long division estimate method first, then solve the same problems using the estimate average technique.

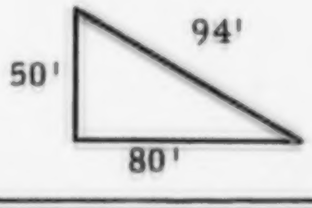
A. Assume you were making a radiograph in a pipe yard and you needed to know what distance from the exposure device your radiation intensity would be 5 mr/hr so that you could place your warning signs at that distance. Your gamma source emits 5,900 mr/hr per curie @ 1 foot. You have a 10 curie source.

B. A 30 curie source of Ir. 192 was being used at ground level. A water tank located 80 feet from the source was being painted. The painters were working on the near side of the tank (80') at a height of 50'. What was their exposure dose rate assuming they remained at the near side of the tank?

Calculations and answers: (for instructors' use)

1. $D = \sqrt{80^2 + 50^2} = 94'$ (Distance to 50' level to tank)
2. $I_1 = 5.9 \times 30 = 177,000$ Mr/hr @ 1

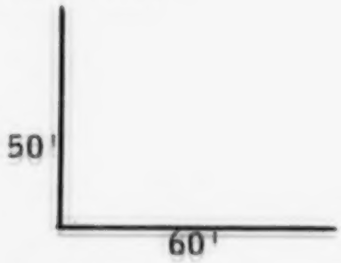
$I_2 - \frac{177000}{94^2} = \frac{177000}{8836} = 20$ mr/hr



IV. TEST (final check on students' comprehension of material presented)

A. Give a brief written test to determine if all class members understand procedure of square root calculations.

1. A cobalt 60 source produces a radiation intensity of 217, 500 mr/hr @ 1 foot. At what distance would the intensity be 1 mr/hr?
2. At a distance 1 the survey meter reads 215 r/hr. At what distance does the meter read 5 r/hr?
3. Meter reads 450 mr/hr @ point 1. A worker on a scaffold 60 feet from point 1 and 50 feet high is exposed to how much radiation intensity.



B. Check answers to the test with the assistance of the class and review problems solving procedures as needed is indicated.

The Next Lesson is: Geometric Principles of Exposure

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 5
Lesson 4
Time 1.5 hours

SUBJECT: Geometric Principles of Exposure

AIM (or purpose): To teach the fundamentals of exposure as related to the geometric arrangement of the exposure setup and develop a thorough knowledge of the subject.

TEACHING AIDS: Spot film viewer
A round cardboard disc taped to the end of a stick or pointer

REFERENCES: Information Sheets No. 6 and No. 7
Nondestructive Testing Handbook, Volume I, 1963, Society for Nondestructive Testing, Evanston, Illinois

I. PREPARATION (of the learner)

Explain briefly that certain very simple and basic laws govern the art of making good radiographs.

X-rays and gamma rays obey the same physical laws as light and formation of shadows or radiation may be better understood by knowledge of these laws. The relationships of source, object and film will have a considerable bearing on the definition in the reproduced image. The skill displayed by the radiographer in image reproduction will depend a great deal on his knowledge of geometric principles and how these factors govern exposure patterns.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Geometric enlargement	1. Explain by chalkboard sketch the enlargement of the image when the film is moved away from the object.

Instructional Topics	Things to Remember to Do or Say
	2. Illustrate the geometric principle by using the spot viewer and the cardboard disc. 3. Use the method of similar triangles to show how the magnification can be predetermined.
B. Distortion	1. Use the spot viewer and cardboard disc to illustrate distortion caused by inclination of the object to the film. 2. Explain the difficulties caused by distorted images: a. A blurred image is hard to identify. b. It is difficult to estimate the actual size of a distorted image.
C. Geometrical unsharpness	1. Show by a chalkboard sketch the formation of penumbra. 2. Use the spot viewer to illustrate penumbra 3. Using the chalkboard sketch, define geometrical unsharpenss. 4. On chalkboard using the method of similar triangles, derive the formula for geometrical unsharpness; i. e., $U_g = \frac{Ft}{d}$ 5. Handout Information Sheet No. 7 (Contains explanation of formula) 6. Display and explain the use of a nomogram for determining geometrical unsharpness. (Nomogram on information sheet #7)

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Have individual students:

A. Draw a sketch of the situation which causes penumbra explaining why and using the spot viewer and disc to illustrate.

B. Explain enlargement of the image in radiography. Use the viewer and disc to illustrate. Show calculation to predetermine the magnification.

C. Outline the consequences of image distortion.

D. Define geometrical unsharpness. Derive the formula and illustrate the use of a nomogram.

Solve the Following Practice Problems:

E. An exposure device's focal spot is positioned 36" from the specimen to be radiographed. The specimen is 12" x 12" x 1" thick. The x-ray film is positioned 12" beyond the specimen, what would be the projection of the image?

F. A flat plate 12" x 12" x 2" thick is radiographed at a film-focal distance of 15". What is the width of the penumbra shadow?

G. Use nomogram to determine the geometric unsharpness in millimeters of a radiograph of a flat plate that is 12" x 12" x 2" thick if the radiograph was made with a Cobalt 60 source 5 millimeters in diameter and a film-focal distance of 20".

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. If the object is placed at 24 inches from the source and the film at 36 inches, what would be the magnification of the image?

B. If a flat plate 1" thick is radiographed using a 20" film-focal distance and a 3 mm diameter source, what is the size of the penumbra?

C. What would be the focal distance to produce a radiograph with no more than 0.2 geometrical unsharpness, if the source is 5 mm diameter and the object is four inches thick?

Check and discuss.

V. SUMMARY

A. Certain geometric principles are applied in radiography.

B. Image distortion is generally caused by improper geometric considerations.

C. Image unsharpness is a major problem when making radiographs.

The Next Lesson is: Logarithms

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 5
Lesson 5
Time 2 hours

SUBJECT: Logarithms

AIM (or purpose): To outline the advantages of the use of logarithms as applied to radiography and to develop ability in their use

REFERENCES: Brief College Algebra, W. L. Hart, 1947, D. C. Heath and Co., Boston, Mass.
Radiography in Modern Industry, 1958, Eastman Kodak Co., Rochester, N. Y. (Page 39)
Information Sheet #8. Logarithm tables. Shielding equations

I. PREPARATION (of the learner)

A. Through adroit questioning determine the level of understanding of logarithms by various members of the class.

B. Explain the importance of using logarithms in radiography pointing out that:

1. Logarithms are used to determine exposure times required to produce satisfactory radiographs.
2. Exposure time varies with film speed. There are many different types of industrial radiography film, each having a different speed.
3. Decay of radioactive materials are logarithmic functions which every radiographer should be able to calculate.
4. Shielding or attenuation properties of the elements are determined by the use of logarithms.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The logarithm	1. Define a logarithm of a number "N" to the base "a" as the exponent of the power to which "a" must be raised to obtain "N". 2. Place the mathematical form on the chalkboard.

	3. Define a natural and common logarithm
B. Properties of logarithms: a. Multiplication b. Division c. Powers	State the rules and illustrate each type of computation on chalkboard.
C. The characteristic and mantissa	Illustrate on chalkboard the integer and decimal parts of a logarithmic expression.
D. Properties of the characteristic and mantissa	List the following theorems--illustrate on chalkboard: 1. The characteristic depends only on the number of digits to the left of the decimal point in the number. 2. When the number is greater than one, the characteristic is an integer which is one less than the digits in the number left of the decimal place. 3. When the number is less than one, the characteristic is negative and equal to the number of spaces left of the decimal to the first significant figure. 4. Explain each of the above by chalkboard example. 5. Show the students a log table Information sheet #8 for determination of the mantissa.
E. Computation with logarithms	Show on the chalkboard simple computations to determine a product, quotient, extraction of roots and determination of a power.
F. The antilogarithm	Define the antilogarithm and illustrate the determination from table and computation. The number corresponding to a given logarithm is called the antilogarithm.
G. Slide rule	Display slide rule and refer students to illustration of scale for determining mantissa logarithms - Page 39 in the Eastman Kodak Textbook.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. List a group of numbers on the chalkboard and ask the students for the characteristic and mantissa of each number. Show each on the chalkboard after students have given the answers.

B. Ask individual students to explain the rules for multiplication, division, and computation of powers by logarithms.

C. State simple problems on chalkboard for student exercise. Solve problems on chalkboard after students have completed calculations. (Furnish mantissa values from log tables).

D. Using equations on information sheet #8, work the following problem: Radiation intensity is 500 mr/hr. How many half-value layers are required to reduce the intensity to 100 mr/hr?

E. How many tenth value layers are required to reduce radiation intensity from 500 mr/hr to 2 mr/hr?

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What is the characteristic and mantissa of the following logarithmic expressions?

a. 1.4271
b. 3.9721
c. 8.4731-10
d. 17.6541-20

B. What is the logarithm of the product of the logarithms: 3.5001 and 5.4379?

C. What is the logarithm of log 5.4970 divided by the log 4.3660?

D. What is the logarithm of $(27.315)^4$ if the mantissa of 273 is .4362.

E. What is the value of 27.315^4 if the antilogarithm of the mantissa .7448 is 5556?

Check and Discuss

V. SUMMARY

A. The whole number of a logarithm is called the characteristic.

B. The fraction of the number is called the mantissa.

C. The characteristic number contains one less digit than the number it represents in log form.

D. The mantissa of a logarithm can be obtained from a log table such as the one used in this lesson.

E. The mantissa can also be found by using a slide rule.

F. Problems of shielding can be solved quickly and accurately by the use of logarithms.

G. Exposure time charts and the characteristic curve of x-ray film are drawn on semi-log paper forms.

The Next Lesson is: Ionizing Radiation

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 6
Lesson 1
Time 1.5 hours

SUBJECT: Ionizing Radiation

AIM (or purpose): To familiarize the student with the basic concepts of radiation physics

TEACHING AIDS: Film: Invisible Bullets, Challenge Series, 45 mins., 16 mm., sound, U. S. Atomic Energy Commission

EQUIPMENT: Film projector and screen

I. PREPARATION (of the learner)

A. Caution group to look for the following points while viewing the film and advise that a test will be given regarding some of these situations later in the session.
   1. Ionization traces in the cloud chamber
   2. The relative energy of the different types of radiation
   3. The type of shielding necessary to stop different types of radiation
   4. The explanation of various terms used in evaluation of biological effects of radiation
   5. The effects of overdosage on the human body
   6. The geiger counter and the different windows used to detect different types of radiation

B. Explain and stress the importance of these situations to the radiographer.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
"Invisible Bullets"	Introduce Film 1. Title 2. Length

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Discuss the film. Emphasize strong points in the discussion. Use questions listed below to spark discussion.

A. The spark chamber and the cloud chamber.
   1. Methods of visually observing ionization from radiation
   2. The ionization path of the different forms of radiation
   3. The effect of radiation on the conductivity of gases

B. The geiger counter and the different window materials needed for the different forms of radiation.

C. The relative penetrating power of different types of radiation.
   1. Lead shielding for gamma
   2. Glass for beta
   3. Paper for alpha

D. The units of measurement for biological radiation effects.
   1. The RAD
   2. The RBE

E. The effects of overdosage on the human body.
   1. Blood damage
   2. Bone marrow damage
   3. Nausea
   4. Lethal dose

F. Why are alpha and beta particles not usually considered hazardous in radiography?

G. When could they create a hazard?

H. Explain whether or not the human body can repair radiation damage.

I. Name three considerations in determining a lethal dose of ionizing radiation to a human being.

J. In what manner may the blood be damaged by ionizing r adiation?

K. What is meant by the relative biological effect?

L. How does a geiger counter measure radiation dose rate?

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What is the effect of radiation on an air path through which it passes?

B. Explain how this can be seen.

C. Which of the three types of radiation (alpha, beta, and gamma) has the greatest penetrating power? The least?

D. Which of these could be shielded by a piece of paper?

E. What is the rad and the rbe? What are they used to measure?

F. Do all forms of radiation have the same biological effects?

G. What is the dosage level considered lethal?

Check and discuss

V. SUMMARY

A. The meaning of radiation, its natural source, the various forms it takes, and how it is used.

B. The difference between alpha and beta particles and between gamma rays and x-rays.

C. The extent of damage to living tissue by ionizing radiation depends on: type and intensity of the radiation; amount and parts of body exposed; duration of exposure.

D. Ionizing radiation can be observed in a cloud chamber instrument.

E. Time, distance, and shielding can reduce the hazards of ionizing radiation.

The Next Lesson is: Isotopes - Excursions in Science

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit	6
Lesson	2
Time	1 hour

SUBJECT: Isotopes - Excursions in Science

AIM (or purpose): To acquaint class members with the basic concepts of the nuclear sciences

TEACHING AIDS: Film: Isotopes - Excursions in Science, 20 mins., 16mm, sound, U. S. Atomic Energy Commission

EQUIPMENT: Film projector and screen

I. PREPARATION (of the learner)

A. Introduce the film by title giving a brief rundown on content pointing out that in order to be able to employ and use radioisotopes in industry one must satisfy the Atomic Energy Commission and/or the State that one fully understands the basic concepts of nuclear science.

B. Suggest that group watch for the following items when viewing the film:

1. The three rays (or particles) ejected by radioactive decay.
2. The definition of half-life.
3. The methods used to create artificial isotopes.
4. The safety precautions used by companies and individuals working with radioactive materials.
5. The encapsulation of radioactive materials.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
"Isotopes - Excursions in Science"	Show the film

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Discuss the film, emphasizing these points in the discussion and questioning as needed:

A. The rays and particles produced by radioactive decay
   1. Alpha
   2. Beta
   3. Gamma

B. Re-define and discuss decay half-life.

C. Production of artificial isotopes used for industrial radiography.

D. Safety equipment used by the workers in the film.

E. Encapsulation, particularly where related to radiography.

F. What is meant when one states that half-life is exponential?

G. Give an example: (If a radioactive isotope is said to have passed through three half-lives what percentage of its original activity remains?

H. Explain why all isotopes of elements are not radioactive.

I. Which of the three emitters has the greatest penetrating power, Alpha, Beta, or Gamma?

J. Which emitter is most suitable for radiography?

K. Why?

L. What are the three basic methods of shielding against nuclear radiation?

M. Why is an isotope that is used in radiography encapsulated?

N. How is the isotope encapsulated?

IV. TEST (final check on students' comprehension of material presented)

NOTE: Oral Quiz

A. What are the three types of particles or rays emitted by radioactive decay?

B. Define a half-life of a radioisotope.

C. How are radioisotopes produced?

D. Why are isotopes used in radiography encapsulated?

V. SUMMARY

A. The three types of radiation produced by radioactive decay.

B. Encapsulation usually eliminates alpha and beta radiation.

C. Half-life of a particular isotope of an element determines its useful life in an industrial application.

D. Safe handling procedures and rules must be understood and observed in order to use and handle radioactive materials.

The Next Lesson is: Atomic Structure of Matter

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 6
Lesson 3
Time 2 hours

SUBJECT: Atomic Structure of Matter

AIM (or purpose): To outline the basic nuclear science concepts and assist the student in developing a proper vocabulary regarding the subject

REFERENCES: Radiological Monitoring for Instructors, Instructor's Guide, Lesson 2, Department of Defense, Office of Civil Defense, Training Division, Battle Creek, Mich.
Information Sheet #41

I. PREPARATION (of the learner)

A. Introduce topic developing interest by asking a few simple questions regarding the structure of matter, supplying quick and informative explanations.

B. Stress the fact that the atomic theory as related to radiography is not difficult to understand if you develop the theory a step at a time. Explain that the purpose of this lesson is to help to visualize the atomic structure of matter and how it can be altered to make gamma radiography possible.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Matter	1. Anything which occupies space and has mass or weight. 2. That which can be classified according to physical and chemical properties. 3. Many different kinds of matter exist. 4. Classification of matter is an important part of nuclear science.

II. PRESENTATION (continued)

Instructional Topics	Things to Remember to Do or Say
B. Classification of Matter 1. Mixture	1. Physical combination of two or more substances characterized by no definite ratio. Each substance maintaining its individual identity: Example: Cup of coffee.
2. Compound	2. Chemical combination of two or more substances characterized by definite ratio of the combining substances. Water contains two parts hydrogen to one part oxygen no matter where it is found.
3. Element	3. Substance which cannot be separated into substances different from itself by ordinary chemical means. Gold is one of the over 100 different substances which contain only atoms of the same chemical property. Silver is another.
4. Molecule	4. Smallest part of a compound that can exist and still retain the chemical properties of the counpound. A molecule contains two or more atoms.
5. Atom	5. Smallest conceivable part of an element. Smallest portion of an element that can enter into chemical combination.
C. Concept of the atom	Information Sheet #41 1. The term "atom" means undividable. It is from the Greek letter "a" meaning "not" and the word "tomos" meaning "cut". 2. The Greek concept proved to be erroneous, and it has been demonstrated, that an atom is dividable. 3. In about 1900 scientists discovered the atom was not a uniform sphere. 4. It was also determined that it contained a strong positive charge in its center with a negative charge about it.

II. PRESENTATION (continued)

Instructional Topics	Things to Remember to Do or Say
	5. The center dimension is small compared to the atom as a whole, about 1 to 10,000 ratio and the negative charges orbit around a nucleus. 6. If the nucleus of an atom was the size of a marble the entire atom would weight about 36 million tons and the closest negative charge would orbit about 200 feet away.
D. Atomic structure	1. An atom consists of protons, electrons, and neutrons. 2. Proton: is a subatomic particle found in the nucleus of an atom. It is positively charged. 3. Electron: a very light particle, negatively charged. Orbits the nucleus. A proton is 1840 times heaver than an electron. 4. Neutron: carries no electrical charge. Weighs the same as a proton and is found in the nucleus. 5. Properties of each element are the period functions of the number of protons in its nucleus.
E. Isotopes of elements	1. Different forms of the same element. 2. Like brothers, they have the same last name but different first names. 3. Each element is assigned an atomic number which is equal to the number of protons in the nucleus of its atom (Sometimes called "Z" number). 4. Each different form, or isotope, of an element has a mass number (The "A" number) The "A" number equals the total number of neutrons and protons in the nucleus of its atoms. 5. Write on the chalkboard the correct symbols for describing cobalt 60.

6. Draw the structure of an atom other than the one shown on information sheet and explain each step. Ask for student participation.
7. Some isotopes are not radioactive. (Stable)
8. Only unstable isotopes can be used in radiography. Explain.

F. Ioniziation

1. A process which results in the formation of electrically charged particles (ions) from neutral atoms or molecules.
2. Ionization is the process and positive and negative ions are products of the process.
3. All three types of radiation, alpha, beta, and gamma. Cause ionization as they interact with various matter.
4. On the chalkboard, demonstrate how radiation strikes orbital electrons and moves them out of orbit.
5. They actually disturb the organized balance of the atomic structure disrupting the normal electrical balance of the atom.
6. Ionization is also the process by which nuclear radiation loses its energy.
7. Ionization permits detection of nuclear radiation, produces the biological effects from nuclear radiation and provides a means of shielding against nuclear radiation.

III. APPLICATION (drill, illustrations, analogies, oral question or assignments)

A. Suggest that students draw an atomic structure without refering to information sheet.

B. Have them state the number of positive and neutral charges in the structure.

C. Ask them to define the "z" number, "a" number.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Oral Quiz

A. Describe a compound, give an example.

B. A mixture, give an example

C. An isotope, give an example

D. Describe the structure of an atom, illustrate on chalkboard.

E. Define ionization.

F. Describe its (ionizations) safety value in radiography.

V. SUMMARY

A. An atom is the smallest part of the elements hydrogen and oxygen. If two atoms of hydrogen and atom of oxygen combine chemically they form one molecule of the compound water.

B. Concepts of the atom

C. Atomic structure

D. Isotopes

E. Ionization

The Next Lesson is: Nuclear Radioactivity

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 6
Lesson 4
Time 2 hours

SUBJECT: Nuclear Radioactivity

AIM (or purpose): To assist the student in developing a basic understanding of the source of the energy emitted from radioactive materials

REFERENCES: Information Sheet #41
Nondestructive Testing Handbook, Volume I, Society for Nondestructive Testing, 1963, Evanston, Illinois

I. PREPARATION (of the learner)

Explain the importance of understanding the radioactive decay process because:

A. The information will aid the radiographer in selection of the proper isotope material for each radiographic assignment.

B. The information is useful in the design of effective shielding.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The structure of an atom	Draw chalkboard sketch of a typical atomic structure. Also use information sheet #41 for this discussion.
B. The atomic nucleus 1. The proton 2. The neutron 3. Atomic number 4. Atomic weight	1. Define: a. Proton - positive parts of atom b. Neutron - neutral parts c. Atomic weight - mass or weight of atom, total number of protons and neutrons in an atom d. Atomic number - total number of protons in an atom 2. Show by sketches why the isotope has the same atomic number but a different atomic weight.

C. Radiation emitters 1. Natural emitters 2. Neutron activated emitters	1. List on chalkboard some natural emitters such as radium - uranium 2. Explain energy equilibrium and radioactive decay. Stable isotopes are in equilibrium - not radioactive. 3. Explain how elements can become radioactive by neutron bombardment - Unstable isotopes are not in equilibrium and decay back to stability. Neutrons upset stability by changing the atomic weight. 4. Illustrate the reaction of a neutron with the element Cobalt 59 to illustrate the formation of Cobalt 60.
D. Products of nuclear radiation 1. Alpha particles 2. Beta particles 3. Gamma rays	1. Define the alpha particle - lightly penetrating highly ionizing stream of fast-moving helium nuclei 2. Explain why the alpha particle is stopped by a small amount of light shielding material. 3. Define a beta particle. 4. List the properties of beta particles - negative charged particle emitted from nucleus of atom. Mass and charge equal to electron. Low penetrating power. 5. Explain the origin of the gamma ray. Short wave length; electromagnetic radiation of nuclear origin, emitted from the nucleus, pure energy. 6. List the properties of gamma rays: a. Electromagnetic energy b. Discrete energy levels c. Penetrating power relatively high 7. Discuss and contrast the electronic and magnetic properties of the three types of radiation.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Have students sketch a model of a typical atomic structure and label each component.

B. Ask students in turn to indicate and define the following:
   1. The proton
   2. The neutron
   3. The Electron
   4. Atomic weight
   5. Atomic number

C. Questions why an element becomes radioactive if an extra neutron is injected into the nucleus.

D. Ask the students what materials are necessary to shield:
   1. Alpha particles
   2. Beta particles
   3. Gamma rays
   4. X-rays

IV. TEST (final check on students' comprehension of material presented)

A. Give brief test:
   1. List the three nuclear disintegration products.
   2. Indicate their penetrating power in increasing order.
   3. Explain the physical difference in the three types of radiation.
   4. Why are alpha and beta particles deflected by a magnetic field when gamma rays are not.
   5. What is the difference between the gamma rays emitted from different radioactive sources?

B. Check answers and discuss with the class.

V. SUMMARY

A. Gamma rays emitted from radioisotopes of elements have discrete energy levels, therefore, the isotope and the element can be identified.

B. Gamma energy is non-magnetic.

C. Beta particles can be deflected in a magnetic field.

D. Gamma rays are pure energy therefore they have no mass.

E. Beta particles have mass or weight.

F. Alpha particles are the least penetrating but are highly ionizing.

The Next Lesson is: X-radiation

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 6
Lesson 5
Time 2 hours

SUBJECT: X-radiation

AIM (or purpose): To explain the theory of x-ray generation and to develop a thorough understanding of the subject

TEACHING AIDS: Chart of the Electromagnetic Spectrum - Page 3- Radiography in Modern Industry

REFERENCES: Nondestructive Testing Handbook, Volume I, Society for Nondestructive Testing, 1963, Evanston, Illinois

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I. PREPARATION (of the learner)

Explain briefly why an industrial radiographer must have an understanding of the principles of x-ray generation. Point out that a knowledge of these principles is necessary to understand the calculations of exposure.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The nature of radiation 1. Rays and/or particles 2. Energy	1. Define electromagnetic wave energy. 2. Explain gamma and x-radiation in terms of rays of energy. 3. Display and explain chart of the electromagnetic spectrum.
B. X-ray generation 1. Decelleration of charged particles 2. Source of particles 3. Target materials 4. Voltage potential 5. Radiation from point of impact	1. Sketch on chalkboard an atomic structure model and a point representing a source of charged particles. 2. Explain: a. The source of charged particles b. Function of the target c. Reason for the high voltage

6. Energy converted to heat	3. Illustrate on the sketch the reaction at the point of impact, showing electron being displaced from orbit. 4. Indicate the efficiency of this system.
C. The continuous spectrum 1. Short wave length limit 2. Effect of kilovoltage	1. Sketch a typical intensity vs. wave length graph on the chalkboard. 2. Define and point out the short wave length limit. 3. Define and explain the effect of decelleration alone on the wave length of radiation. 4. Sketch in additional curves to show the effect of changing kilovoltage.
D. The characteristic spectrum 1. Critical voltage 2. Definite wave lengths	1. Add a characteristic line to the chalkboard sketch. 2. Explain the origin of this line. 3. Use chalkboard to define the critical voltage. 4. Explain the relation between the characteristic wave length and the orbits of the atomic structure.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Using a sketch of an atomic structure on the chalkboard or on a passout sheet have students identify the parts of the structure and indicate the source of charged particles.

B. Have students indicate the following:
1. The reaction which produces the continuous spectrum.
2. The reaction which produces the characteristic spectrum.
3. The effect of increasing the kilovoltage by drawing a graph of intensity vs. wave length.

IV. TEST (final check on students' comprehension of material presented)

A. Suggested questions for written test:
1. Explain radiation in terms of rays of energy.
2. What is the function of the target?
3. What is produced at the target besides radiation?
4. Why does decelleration produce white radiation?
5. What is the effect of kilovoltage on the short wave length limit?

B. Review answers with the class allowing brief time for students to make needed corrections.

The Next Lesson is: The Effects of Radiation on Physical Matter

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 6
Lesson 6
Time 2 hours

SUBJECT: The Effects of Radiation on Physical Matter

AIM (or purpose): To outline and thoroughly explain the reactions which occur within a material when it is subjected to radiation

REFERENCES: Nondestructive Testing Handbook, Volume 1, Society for Nondestructive Testing, 1963, Evanston, Illinois
Information Sheet #9, Scattering Effect

I. PREPARATION (of the learner)

A. Impress upon the students the need for developing a thorough understanding of the subject and how this knowledge can affect the personal safety of the individual.

B. Help him to understand the damage that could be done to his body.

C. Attempt to develop a sense of responsibility in each student that untoward actions on his part may affect not only his but the safety of others as well.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Scattering	Pass out Information Sheet #9
1. Coherent energy scattering	1. Draw sketch of typical atomic structure on chalkboard.
2. The Compton effect	2. Explain on the sketch:
3. Pair production	a. The reaction in coherent scattering
4. Photoelectric effect	b. The dual Compton reaction
	c. The formation of the particles in pair production
	d. The formation of the particle in the photoelectric effect
	e. The fluorescence of certain materials

	3. Compare and contrast the four common types of scattering.
B. Ionization 1. Photon 2. Electron	1. Draw sketch on chalkboard of atomic structure as an ion. 2. Define an ion. 3. Explain how an ion can be created by a photon of energy 4. Indicate how the ejected electron can create other ions. 5. Point out useful utilization of the ionizing effect. a. Sterilization of food b. Radiation detection instruments 6. Explain metallic bonding and show why metals are not permanently affected by irradiation.
C. Permanent effects	Point out that: 1. Irradiation does not leave the material in a state of radioactivity. 2. Most ionization is permanent.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Give individual students one of the following problems to be illustrated on chalkboard:

1. Coherent energy scattering
2. The compton effect
3. Pair production
4. Photoelectric effect
5. Creation of an ion by a photon of energy
6. Creation of an ion pair by a photon and the ejected electron

B. Have each student explain his subject to the rest of the class asking the group to offer comments or questions as the subject is developed.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. Why does radiation cause ionization?

B. What is the difference between coherent and incoherent (Compton) scattering?

C. Does irradiation leave any residual radioactivity? (Explain)

D. Describe a use of ionizing radiation.

E. Contrast pair production with the Compton effect.

Check papers and discuss.

V. SUMMARY

A. Radioisotopes normally used in industrial radiography do not affect the materials being radiographed.

B. Radioisotopes normally affect only living matter.

C. Ionization can damage or destroy living tissue.

D. Ionizing radiation can be created in several ways.

The Next Lesson is: Biological Effects of Nuclear Radiation

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 6
Lesson 7
Time 1.5 hours

SUBJECT: Biological Effects of Nuclear Radiation

AIM (or purpose): To develop an awareness of the effects of nuclear radiation on the radiographers' personal health

REFERENCES: Title 10, Federal Register, Part 20, U. S. Atomic Energy Commission, Washington, D. C. Radiological Health Handbook - U. S. Dept. of Health, Education and Welfare - Public Health Service, Washington, D. C. Distributed by U. S. Dept. of Commerce - Office of Technical Services.
Information Sheet #10

I. PREPARATION (of the learner)

A. Point out that this lesson will help to insure the future health of the radiographer.

B. That it can also help to prevent serious injury to the radiographer.

C. Stress that it will help the radiographer to understand why his employer has certain safety rules which the radiographer must observe if he is to keep his job.

D. Explain that it will provide a thorough understanding of the biological effects of ionizing radiation and precautionary measures that must be taken, if a person is to be licensed to use, possess, and handle radioactive materials.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Types of exposure	Pass out Information Sheet #10
1. External radiation	1. Explain the difference between:
2. Inhalation and ingestion	a. External exposure b. Inhalation and ingestion
3. Energy level of radiation	2. Emphasize the increased hazard of inhalation particularly of blood soluble elements.

II. PRESENTATION (continued)

Instructional Topics	Things To Remember to Do or Say
	3. Explain the effect of exposure from increasingly higher energy radiation.
B. Immediate effects 1. Radiosensitivity 2. Erythema 3. Blood blisters 4. Drying of mucous	1. Explain the immediate effects of the ionization of sensitive tissue. 2. Point out the immediate skin disorders which indicate over-exposure. 3. Explain other side effects such as: nausea, lifeless feeling, and general ill feeling.
C. Delayed effects 1. Genetic effects 2. Scar tissue 3. Cancer	1. Explain the function of chromosomes. 2. List some changes in offspring caused by alteration of chromosomes a. Possible deformation b. Features unlike either parent 3. List the effects on cancer formation: a. Heavy over-exposure could cause cancer. b. Exposure can cause accerlerated growth of existing cancer. c. Radiation can sometimes destroy cancer. 4. Tissue which has been damaged remains as scar tissue without useful function.
D. Permissible dosages 1. Roentgen 2. Rem 3. Biological limitations 4. Legal limitations a. whole body b. partial exposure	1. Define a roentgen and a rem on chalk-board 2. Explain the relation of a roentgen to the rem. 3. Outline the following biological effects: a. 50 to 100 rem—temporary blood changes b. 100 rem and greater - erythema, blood blisters, inflamation of mucous membranes, possible fatality c. 450 rem and greater - 50% chance of survival, loss of hair, changes in nails 4. Indicate the whole body dosage allowed by law; a. 1250 millirem every 13 weeks b. 5 rem per year c. Life time dosage determined by the formula 5 (N-18) Explain fully

5. Outline the partial exposure allowed by law for persons in restricted areas:
    a. Hands and forearms, feet and ankles - 18 3/4 rems every 13 weeks
    b. Skin of whole body - 7 1/2 rems in 13 weeks
6. Outline the whole body dosage allowed by law for person outside restricted areas:
    a. Maximum of 1/2 rem in one year
    b. No more than 100 millirem in seven days

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Invite the students to discuss and list the biological effects of exposure to ionizing radiation.

B. Discuss the effects listed.

C. Have members of the class give the legal permissible dosages for whole body exposure in restricted and unrestricted areas.

D. Ask for exact definitions of a roentgen and a rem.

E. Discuss the limits and effects of massive doses of radiation— chances of survival and visible effects.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. List the permissible legal dosages for whole body exposure.

B. If a group of adults was exposed to a short term, whole body dose of 450 rems of radiation what percentage would probably survive?

C. List five effects of excessive exposure of the human body to nuclear radiation.

D. Why does the higher energy radiation have a greater biological effect?

E. From what dosage level of exposure would the average person completely recover from all ill effects?

Check papers and discuss

V. SUMMARY

A. The total permissible accumulated radiation dose is determined by a formula: 5 (N-18).

B. The permissible dose varies with individual parts of the body.

C. Detailed, current dose records of personal radiation exposure must be kept.

D. Ionizing radiation can destroy cancer cells but can also cause growth of existing cancer cells.

E. Internal radiation exposure to alpha, beta, or gamma radiation can be caused by inhalation or ingestion of contaminated air, food, or water.

The Next Lesson is: Methods of Reducing Radiation Dosage

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 6
Lesson 8
Time 2 hours

SUBJECT: Methods of Reducing Radiation Dosage

AIM (or purpose): To develop a working knowledge of the methods used to reduce unwanted radiation intensities

TEACHING AIDS: Small source of radioactivity
Samples of shielding materials
Dosimeters

REFERENCES: Nondestructive Testing Handbook, Volume I, Society for Nondestructive Testing, 1963, Evanston, Illinois
Information Sheet #11

I. PREPARATION (of the learner)

A. Review the important points on effects of radiation convered in the two previous lessons.

B. Introduce the three essential ways of reducing or controlling radiation dosage when working with radioactive materials.

C. Explain why it is essential for a radiographer to understand methods of reducing radiation dosage.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Time of exposure	Pass out Information Sheet #11 1. Explain the concept of dose rate and total dosage. 2. Demonstrate: a. Place two dosimeters at a fixed distance from a source of radiation. b. Remove one dosimeter after a short period.

c. Remove the second after twice the time of the first.
d. Have students read and report the results of both dosimeters.
e. Discuss the results & why.

B. Distance from Source

1. Review the inverse square law.
2. Demonstrate:
    a. Place one dosimeter a fixed distance from the source and a second at twice the distance.
    b. Expose both for the same period of time.
    c. Have students read and report the results of both dosimeters.
    d. Discuss the results & why.

C. Shielding of Source

1. Explain absorption and attenuation of radiation by shielding.
2. Demonstrate:
    a. Place two dosimeters at a fixed distance from a source of radiation.
    b. Place shielding material between source and one dosimeter.
    c. Remove both dosimeters at the same time.
    d. Have students read and report the results of both dosimeters.
    e. Discuss the results & why.
    f. Explain the "Half-Value and Tenth-Value Layers"
        1. Amount of any shielding materials required to reduce radiation intensity to one-half.
        2. Amount required to reduce to one-tenth.

III. APPLICATION (drill, illstrations, analogies, oral questions or assignments)

A. Repeat the three preceding demonstrations.

B. For the "Time of Exposure" demonstration have students estimate the dosage of the second dosimeter before reading.

C. For the "Distance from Exposure" demonstration have students calculate the dosage on the second dosimeter before reading.

D. For the "Shielding of Source" demonstration use several dosimeters and layers of shielding material to obtain data for the plotting of a curve of dosage vs. thickness.
Ask the students to estimate the thickness of the material to reduce the dosage to half of that without shielding.

IV. TEST (final check on students' comprehension of material presented)

A. Ask class to write answers to the following questions:
   1. Name the three factors in the control of dosage.
   2. If a radiographer receives a dose of 7 mr/hr from a source by standing 100 feet away for 5 minutes, how much will he receive in 12 minutes?
   3. If a radiographer receives a dose of 7 mr/hr from a source by standing 100 feet away for 5 minutes, how much would he receive in 5 minutes at 75 feet away?
   4. How thick is a Half-Value Layer? A tenth-value layer?

B. Check and discuss answers given. Make sure all class members understand correct answers.

V. SUMMARY

Emphasize the following major points:

A. Time, distance and shielding are the three most important radiation protection factors.

B. Radiation intensity is inversely proportional to the square of the distance of source of radiation.

C. All materials having density and mass have some radiation shielding value.

D. Time spent in radiation field is proportional to the total exposure dose.

The Next Lesson is: The Calculation of Shielding Thickness

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 6
Lesson 9
Time 2 hours

SUBJECT: The Calculation of Shielding Thickness

AIM (or purpose): To develop understanding and ability in making calculations required for determining the thickness of radiation shielding

REFERENCES: Radiation Safety in Industrial Radiography with Radioisotopes, P.M. Frazier, C.R. Buchanan, and G.W. Morgan, 1954, U.S. Dept. of Commerce, Washington, D.C.
Information Sheets #8, #9, #12

I. PREPARATION (of the learner)

A. Introduce the topic and briefly review the need for shielding radioactive sources and radiographers from ionizing radiation.

B. Outline some of the subjects to be studied explaining why it is important to know the thickness of a half or tenth value layer, the location of shielding material, its properties and amounts needed for varying source intensities.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Absorption of gamma radiation 1. Compton effect 2. Photoelectric effect 3. Pair production	Refer to information sheet #9 and review mechanisms of attenuation of a photon beam as it passes through a material.
B. Geometry of Absorption 1. Narrow beam 2. Broad beam	1. Define the two terminoligies and contrast their meanings: a. Broad beam shielding includes the effects of scattered radiation resulting from deflection of the primary radiation as well as absorption of the primary radiation.

Instructional Topics	Things to Remember to Do or Say
	b. Narrow beam shielding does not include the effects of scatter from the shield. 2. Explain the importance of determining the method of calculation. 3. Questions
C. Calculations of narrow beam shielding $I = I_0e - ut$	1. Define the terms of the equations on the chalkboard: Reduction factor ≐ eut e = 2.718 (A constant) u = the linear absorption coefficient t = thickness of shield (in centimeters) $I = I_0e - ut$ I_0 = the original radiation exposure rate I = the attenuated radiation exposure rate e = 2.178 (a constant) u = the linear absorption coefficient t = the thickness of shield in centimeters 2. Show calculations of a typical problem in shielding. 3. Questions
D. Emperical data for broad beam absorption	1. Define: a. Reduction factor - $\frac{\text{Dose rate without shield}}{\text{Dose rate with shield}}$ b. Half-value and tenth-value layer - amount of shielding material required to reduce radiation intensity to one half its original value Tenth value layer - amount of shield material required to reduce radiation intensity to one-tenth its original value 2. Explain the origin of the NBS curves for broad beam absorption. 3. Demonstrate the determination of shielding thickness by use of half-value layers. Explain and discuss

	4. Tabulate on the chalkboard the values of half value and tenth value layer of iron, lead, and concrete for Cobalt, Iridium, and Cesium radiation. 5. Distribute copies of the NBS reduction factor curves for broad beam shielding and information sheets 12A, 12 B, 12C. 6. Explain and discuss.
E. Relative efficiency of shielding materials	Hand out information sheet #13 - Explain and discuss
F. Equation for determining the number of half-value layers required to reduce primary radiation to an acceptable level and equation for tenth-value layers (Logarithmic method)	Refer to Information Sheet #8: 1. Write both equations on chalkboard. 2. Have students copy them. 3. Work two problems on chalkboard using each equation. 4. Prove validity of answers,

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III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Ask students to define broad and narrow beam absorption and to explain the limitations of the calculations from narrow beam absorption.

B. Request others to define the Compton effect, photoelectric effect, and pair production.

C. Have another define the reduction factor, half-value layer, and tenth-value layer.

D. Suggest members of the group use or explain the NBS curves for broad beam absorption.

E. Have each individual determine the number of half-value layers to reduce an Iridium 192 radiation intensity of 1000 mr/hr to 10 mr/hr. Ask for verbal replies and demonstrate the solution.

F. Ask the students to determine the thickness of lead, iron, and concrete which corresponds to the half-value layers in the above problem.

G. Invite all class members to work two shielding problems requiring the use of the logarithmic method for solving the problems as explained in step II. Discuss answers. Review the equations if necessary.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. Define:
1. Half-value layer
2. Tenth-value layer
3. Reduction factor

B. How many half-value layers are needed to reduce a radiation intensity of 250 mr/hr to 2 mr/hr?

C. How much lead shielding is required to reduce the level of Cobalt 60 from 250 to 2 mr/hr?

D. What thickness of lead is required if the information is taken from the NBS absorption curves?

E. What is the difference between narrow beam and broad beam absorption?

Check and discuss.

V. SUMMARY

A. Shielding can be achieved with any relatively non-porous material or anything that has mass or weight.

B. The required amount of shielding can be calculated by several methods.

C. Shielding from contamination is not as simple as shielding from a point source of radiation.

D. A mixture of several different types of material is sometimes used as shielding; i.e., concrete, steel, sand, water, wood, etc.

The Next Lesson is: Elements of Electrical Circuits

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 6
Lesson 10
Time 1.5 hours

SUBJECT: Elements of Electrical Circuits

AIM (or purpose): To outline and acquaint the student with the fundamentals of electronic circuitry

TEACHING AIDS: Film: Elements of Electrical Circuits, 11 mins., 16 mm, sound, Pennsylvania State University, University Park, Pa.

EQUIPMENT: Film projector and screen

I. PREPARATION (of the learner)

A. Point out that an understanding of the fundamentals of electronic circuitry is necessary if the student is going to use and maintain x-ray generating, portable power generating, and nuclear radiation detecting equipment properly and in a non-hazardous manner.

B. Invite special attention to the definitions of the following terms by the student:
   1. Conductivity
   2. The amp
   3. The volt
   4. Resistance and the ohm
   5. Ohm's Law

C. Caution the group that a test will be given at the conclusion of the film showing.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
"Elements of Electrical Circuits"	Review film before showing to students. Make notes of key points and inform students of these key points before showing them the film.

II. PRESENTATION (continued)

Instructional Topics	Things to Remember to Do or Say
	Have film and projector set up before students arrive.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Discuss the film, emphasizing these points in the discussion.

A. The definition of the terms:
   1. Conductivity
   2. Insulators and conductors
   3. The volt, amp, and ohm

B. Ohm's Law and its application

C. The effects of heat on resistance

D. The effects of size and length of the conductor on resistance

IV. TEST (final check on students' comprehension of material presented)

NOTE: Oral Quiz

A. If a six volt battery was connected across a 3 ohm resistor, how many amps would flow?

B. Define:
   1. Resistance
   2. Amperage
   3. Voltage

C. What happens to the electrons in a conductor when a voltage is applied? How is this related to the atomic bonding in metals?

V. SUMMARY

A. In order to understand the behavior of electric power one must first learn to understand the basic laws pertaining to this subject.

B. The terms used in applying these laws must be interpreted properly.

C. Students must learn to use these circuits in a non-hazardous manner.

The Next Lesson is: Gamma Ray Apparatus

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 7
Lesson 1
Time 1.5 hours

SUBJECT: Gamma Ray Apparatus

AIM (or purpose): To provide knowledge and understanding of the characteristics of gamma ray exposure apparatus

TEACHING AIDS: Sample radiographs
Film viewer

REFERENCES: Nondestructive Testing Handbook, Volume I, Society for Nondestructive Testing, 1963, Evanston, Illinois
Radiography in Modern Industry, Eastman Kodak Company, 1958, Rochester, N. Y.

I. PREPARATION (of the learner)

A. Introduce subject and explain the usefulness of the information to be given in this lesson; point out that it will aid the radiographer in obtaining better radiographs making his job easier and safer.

B. Stress the fact that a thorough understanding of the equipment and its capabilities will result in improved techniques and economic advantages.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Penetrating power of gamma rays	1. List on the chalkboard and explain, the useful range of penetration for Cobalt, Iridium, Cesium and Radium. 2. Explain the term KEV and MEV. 3. List the KEV range or MEV range of the three synthetic isotopes - cobalt, iridium, and cesium. 4. Explain main energy spectrum of CO 60, i.e., 1.1 MEV and 1.3 MEV.

B. Quality of Radiation	1. Define radiation quality. 2. Explain: a. Why the radiation quality of gamma radiation is fixed b. The effect of the fixed radiation quality on the latitude of thickness c. The difficulties of sensitivity control with isotope radiation 3. Show sample radiographes 4. Questions
C. Safety	1. Point out the hazards of the continuously active source: a. Cannot be turned off while being transported b. During periods of storage c. Between exposures d. In the event of capsule rupture 2. Explain the problems of shielding: a. Other workers b. Confined areas c. Scaffolds d. Congested areas e. Uncontrolled areas 3. Questions
D. Disadvantages of gamma radiation	Discuss: 1. The cost of source replacement 2. The expense of safety programs 3. The limitations for inspection of thin or light materials 4. Questions
E. Advantages peculiar to gamma radiation	Explain: 1. Equipment mobility 2. Self containment 3. Unrestricted beam geometry 4. Questions

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III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Discuss the following questions:

A. What is the useful thickness range (in steel) of radiation from Iridium 192? Cobalt 60? Cesium 137?

B. What is the KEV range of Iridium 192? Cesium 137?

C. What is the MEV of the two Cobalt 60 gammas?

D. What is the duty cycle of isotope radiation?

E. What is the greatest operational disadvantage of isotope radiation?

F. Why are the shielding requirements greater for Cobalt than Cesium?

G. Why is gamma radiation ineffective for inspection of light materials such as aluminum and magnesium?

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. Define KEV and MEV.

B. List the useful range of thickness for radiography with:
   1. Cobalt 60
   2. Iridium 192
   3. Cesium 137

C. What effect on contrast would result from changing the radiographic technique of a 1/4" steel plate from the use of Iridium to Cobalt?

D. What is the greatest advantage of gamma radiation for radiographic use?

Check and discuss

V. SUMMARY

A. Gamma rays have relatively more penetrating power than portable x-ray generators.

B. Gamma radiation cannot be shut off.

C. Gamma ray uses are more flexible than those of x-ray generators.

D. Gamma rays are unsuitable for radiographing thin, light metals and plastics.

E. Gamma ray intensity decays with time.

The Next Lesson is: X-ray Apparatus

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 7
Lesson 2
Time 1.5 hours

SUBJECT: X-ray Appartus

AIM (or purpose): To familiarize the student with the characteristics of x-ray generators and x-ray apparatus

TEACHING AIDS: Sample radiographs
Film viewer
X-ray generator and apparatus

REFERENCES: Nondestructive Testing Handbook, Volume I, Society for Nondestructive Testing, 1963, Evanston, Illinois
Radiography in Modern Industry, Eastman Kodak Co., 1958, Rochester, N. Y.
Information Sheet #14

I. PREPARATION (of the learner)

A. Arrange the class in good viewing position around the x-ray apparatus and point out the essential parts and characteristics of the equipment.

B. Give a brief review of the capabilities and uses of x-ray with special emphasis on industrial application.

C. Point out that each student will be given individual instruction on how to use x-ray apparatus.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Penetrating power of x-ray apparatus	1. List on the chalkboard the range of penetrating power for portable generators, fixed generators, and accelerations. Portable x-ray generators range: about 1/8" to 1 1/2" steel equivalent. Fixed type:

1/4" to 2 1/2"; accellerators up to 12" or more.

2. Explain how penetration power can be varied by changing kilovoltage.
3. Point out that as x-ray wave length decreases, the penetrating power increases.

B. Quality of radiation

1. Define radiation quality. X-ray quality can be compared to the KV or wave length of the x-rays being generated.
2. Explain:
   a. How radiation quality can be varied on an x-ray generator by changing KV setting
   b. The effect of radiation quality on thickness latitude
   c. The ability to adjust sensitivity by changing the radiation quality
3. Show sample radiographs of the above.
4. Hand out Information Sheet No. 14.

C. Safety

1. Point out the advantages of electrically generated radiation from a safety standpoint. Radiation can be turned off when not in use.
2. Explain why x-rays are easier to shield than higher energy gamma radiation. The higher the energy the more shielding necessary.

D. Disadvantages of x-ray apparatus

1. Define duty cycle and constant potential. Explain the length of time than an x-ray generator can be operated without overheating tube is called duty cycle.
2. Explain why cooling is required in the operation of x-ray generators. Cooling required to protect target and tube.
3. Point out the disadvantages of:
   a. Large size of x-ray tube heads
   b. Electrical power requirements
   c. Restricted beam geometry of tank units
   d. Restircted duty cycle because of

excessive heat generated by electrons striking target in x-ray tube.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Ask the class to assist in answering the following questions:

A. What is the thickness range in steel of x-rays from a 200 KVP x-ray generator?

B. How can penetrating power be adjusted on x-ray generators?

C. What effect does radiation quality have on the latitude of thickness which can be covered by a single exposure?

D. How does radiation quality effect sensitivity?

E. Why are x-rays from portable generators easier to shield than gamma rays?

F. What is meant by an x-ray generators duty cycle?

G. How can the duty cycle be increased?

H. List four disadvantages of x-ray generators?

IV. TEST (final check on students' comprehension of material presented)

A. Suggested questions for oral or written test:
   1. Define radiation quality.
   2. What happens to the wave length of the radiation when the KV is increased?
   3. Define thickness latitude capability.
   4. List three safety features of x-ray generators.
   5. What is meant by a constant potential x-ray generator?

B. Discuss correct answer for each question included in the test and clarify any additional questions class members may have about x-ray apparatus.

The Next Lesson is: Decay of Radioactive Materials

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 7
Lesson 3
Time 1.5 hours

SUBJECT: Decay of Radioactive Materials

AIM (or purpose): To develop an understanding of radioactive decay mechanisms

REFERENCES: Nondestructive Testing Handbook, Volume I, Society for Nondestructive Testing, 1963, Evanston, Illinois
Information Sheets #15, and #16

I. PREPARATION (of the learner)

A. Write aim of lesson on chalkboard explaining that the lesson is calculated to help the radiographer in selecting the proper source of radiation for a particular assignment and should help him understand the safety requirements for each type of source.

B. Briefly review previously discussed material by holding a short discussion, on alpha and beta particles, gamma photons and where these energy forms originate.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Disintegration mechanisms	1. List the four modes of disintegration alpha particle emission, beta and positron particle emission and "K" capture. 2. Define electron or "K" capture, i.e., electron capture from the "K" shell by the nucleus of the atom. 3. Define: a. Alpha particle - stream of fast moving helium nuclei, highly ionizing, weakly penetrating

        - b. Beta particle - negatively charged particle emitted from nucleus
        - c. Gamma photon - short wave length, electromagnetic radiation of nuclear origin.
    4. Questions

B. Disentegration scheme

1. Draw chalkboard sketch of Cobalt 60 decay scheme explaining:
    - a. The intermediate gamma emission
    - b. The two beta disintegrations
    - c. The final two gamma emissions
    - d. The formation of stable Nickel 60
2. Questions

C. Decay half- life

Refer to information sheets #15 and 16

1. Define half-life and decay rates on chalkboard.
2. List the half-life values for:
    - a. Cobalt 60 = 5.3 years
    - b. Iridium 192 = 75 days
    - c. Cesium 137 = 27 years
3. Sketch a half-life decay curve on the chalkboard, explaining its use.
4. Questions

D. Decay tables

1. Explain the advantages of decay tables:
    - a. Helps in figuring exposure time accurately and quickly
    - b. Reduces calculation errors
    - c. Helps to project future needs of replacement source capsules
2. Work sample problems using decay tables.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Have the group list the four modes of disintegration.

B. Ask students to define each mode and discuss.

C. Request students draw the Cobalt 60 decay scheme and explain.

D. Ask the following questions and discuss each:
   1. What is meant by half-life?
   2. What is the half-life of Iridium 192? Cobalt 60?
   3. What is the value of the decay chart?

E. Have students work the following problem using a Cesium decay chart:
   1. 5 Curie Cesium 137 source was purchased in 1959. When will its remaining activity be 30% of its original activity? What is its activity now?
   2. Using Cobalt tables (Information Sheet #15) what is the remaining activity of a 2 curie Cobalt 60 source that was encapsulated in September 1960?

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. Why are the two beta disintegrations of Cobalt 60 not used in industrial radiography?

B. Does nuclear disintegration always produce a stable element– Explain.

C. How long is a half-life?

D. What is the half-life of Cobalt 60? Iridium 192?

E. Define K capture?

F. What is the result of K capture?

G. How many half-lives has a cobalt 60 source had if it is 21.2 years old?

H. What percentage of its original activity does it still retain?

Check and discuss.

V. SUMMARY

A. Time required for a radioactive isotope of an element to lose one-half of its original energy or intensity is called half-life.

B. Long half-life is desirable in selecting a radioactive isotope for use in radiography.

C. Only a few radioisotopes are economically useful in industrial radiography.

D. Most radioactive isotopes are either too weak having a long wave length or have an undesirable half-life, or a combination of both.

The Next Lesson is: Construct an Isotope Decay Chart

INSTRUCTOR'S LESSON PLAN
Manipulative Skills

Unit 7
Lesson 4
Time 2 hours

JOB (or operation): Construct an isotope decay chart

AIM (or purpose): To develop skill in the preparation of decay charts and to develop an awareness of the importance of decay charts

MATERIALS: Pencils, straightedge, and eraser
Cartesian coordinate paper
Semi-log paper, 2 cycle, 70 divisions

REFERENCES: Information Sheet #17

I. PREPARATION (of the learner)

Introduce the subject and stress that this lesson is recommended to enable one to find the source strength of a capsule so that accurate exposure time can be calculated. It should also help to project the basis for source capsule replacement.

II. PRESENTATION (of the skills)

Operations or Steps	Key Points (things to remember to do or say)
A. Place semi-log paper on table	1. Pass out information sheet # 17, 2. Place log scale vertically facing upward.
B. Title the paper	Write the following in the upper right hand corner: 1. The source model and serial number 2. The type of radioactive material 3. The date of chart preparation
C. Label coordinates on paper	1. Label the log scale as "Activity in Curies". 2. Label the arithmetic scale in months or years according to type of source.

	3. Start with the month or year the isotope was measured. 4. Use abbreviations to avoid cluttering paper, 5. The scale across the bottom should cover the period of usefulness of the source.
D. Mark the present activity	1. Determine source activity from manufacturers data or measurements previously made on the source. 2. Place mark on the chart for this activity. 3. Mark is placed at point representing the date of measurement.
E. Mark the activity at one-half the life-decay period from the present	1. The source activity will be one half the present value in one half-life period. 2. Mark the time on the scale across the bottom of the paper, 3. Mark the source activity for that date.
F. Draw the decay curves	1. Connect the lines between the present and the first half-life activities. 2. Extend the curve for the entire period of the graph.
G. Semi-log paper	1. Give advantages of using semi-log paper for this chart. 2. Compare a chart made on semi-log paper to a chart made on cartesian coordinate paper. 3. Questions

DEMONSTRATE AGAIN BUT HAVE THE STUDENTS INDICATE THE PROPER SEQUENCE AND PROCEDURE.

III. APPLICATION (practice by learner under close supervision)

A. Supervise the students in the preparation of a decay chart for 75 curies of Iridium 192 using the steps outlined in Step II.

B. Have group prepare a chart for twenty years decay of 30 curies of Cobalt 60.

C. Suggest students prepare Iridium 192 decay chart substituting cartesian coordinate graph paper for semi-log graph paper.

D. Compare the two charts and invite students to explain the advantages of using semi-log graph paper.

IV. TEST (performance of skill to acceptable standards)

NOTE: Written Test

A. Prepare a decay chart on 50 curies of Iridium 192.

B. Develop a decay chart on 20 curies of Cobalt 60.

C. Determine the strength of the Iridium source 60 days from now. 6 months later.

D. Show the Cobalt source will have one-fourth the activity of the present time.

E. What is meant by a half-life of decay? Check and discuss.

V. SUMMARY

A. Decay charts save time when making calculations for radiographic exposures.

B. Semi-log paper condenses the size of charts necessary to plot decay and straighten the curve.

C. Separate decay charts are necessary for each type of radioisotope because of differences in decay rates.

D. Decay charts are not used in x-ray exposure calculations.

The Next Lesson is: Chemistry of Iron and Steel

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 8
Lesson 1
Time 1 hour

SUBJECT: Chemistry of Iron and Steel

AIM (or purpose): To acquaint the class members with the basic metallurgical processes in iron and steel refining

TEACHING AIDS: Film: Chemistry of Iron and Steel, 14 mins., 16 mm, sound, U.S. Steel Corperation
16 mm projector
Pieces of metal with defects

REFERENCES: Metals Handbook, 1948 Edition, American Society for Metals, Cleveland, Ohio

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I. PREPARATION (of the learner)

This film will illustrate how certain types of defects originate in steel plate, forgings and castings. The radiographer's job will include locating and identifying these defects. Gas bubbles as well as solid materials trapped in the solidified metal are considered defects.

Point out the following to be noted during the showing of the film:

A. The product of the blast furnace is iron.

B. The product of the open hearth and electric furnaces is steel.

C. Iron must be separated from other elements before it is of commercial value.

D. Very high temperatures must be used to accomplish separation of iron from other chemicals.

E. Other chemicals are added to the iron and steel to cause reactions that produce slag and gases.

F. Notice the melting temperature of iron as given in the film.

G. Announce to the class that an oral test will be given after the film is viewed.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. "The Chemistry of Iron and Steel"	Show the film NOTE: The film should be viewed by the instructor in advance to showing it to the class. Detailed notes should be made by the instructor on important information presented by the film for use in class discussion after the film showing.
B. Causes of defects in metals	Review the basic causes of defects in metals and relate to the information presented in the film. Explain how these defects makes radiography necessary.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Discuss the film. Note the following points and invite comments from the students:

1. The purpose of the blast furnace
2. The purpose of the open hearth and electric furnaces.
3. The materials which are charged to each type furnace.
4. The temperatures required for the making of iron and steel.

B. Show class examples of metal with defects and discuss what caused the defects.

IV. TEST (final check on students' comprehension of material presented)

Give verbal quiz. The following questions are suggested:

A. What is the product of the blast furnace?

B. What is the product of the open hearth furnace?

C. What is the material charged to the blast furnace?

D. What is the temperature of the iron in the bottom of the blast furnace?

E. What are the bubbles that rise to the top of the metal in the open hearth furnace?

F. What are some typical defects in metal and what are their causes?

The Next Lesson is: Semi-finished Steel

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 8
Lesson 2
Time 1 hour

SUBJECT: Semi-finished Steel

AIM (or purpose): To teach the basic metallurgical practices employed in steel making

TEACHING AIDS: Film: Semi-Finished Steel, 8 mins., 16 mm, sound, United States Steel Corporation

EQUIPMENT: Film projector and screen

REFERENCES: Metals Handbook, 1948 Edition, American Society for Metals, Cleveland, Ohio
Nondestructive Testing-Introduction PI-4-1, 1964, General Dynamics-Convair, San Diego, California

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I. PREPARATION (of the learner)

A. Introduce the film, pointing out some of the features to watch for:
   1. The castings of the ingot
   2. Various types of ingot molds
   3. Addition of aluminum during pouring
   4. The squeezing of the metal as it passes through the rolling mill

B. Stress that this information will help the radiographer to better understand how some defects are removed while some remain in the ingots.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
"Semi-finished Steel"	Show the Film

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Have students discuss the practice of pouring the ingot:
   1. The use of the various types of ingot molds
   2. Hot topping molds
   3. Cropping of molds after solidification
   4. The source of future defects from improper cropping

B. Discuss the practice of deoxidation in the mold:
   1. The addition of aluminum and/or silicon to control gases in the steel
   2. The source of future defects from improper deoxidation

C. Discuss the reason for reducing the steel in several passes instead of one and the problem of internal rupture from excessive single pass reduction.

D. Discuss the problem of laminations and the effect of gas bubbles which do not weld during rolling.

E. Invite questions from students for further discussion.

F. Reshow film if all points or questions have not been cleared up.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What is the purpose of the hot top on an ingot mold?

B. Give reasons for the addition of aluminum during pouring.

C. What happens to the gas bubbles in the ingot when it passes through the rolling mill?

D. Why is the top of an ingot mold cut off and discarded?

E. What type of defect can be caused by poor stirring of the materials added for deoxidation, i.e., aluminum and silicon?

Discuss test results - give help where needed

V. SUMMARY

A. Casting of semi-finished steel requires many methods of removing undesirable components and discontinuities from the ingot.

B. It is important that the correct amounts of each material be added to the steel before the ingot is poured so that the ingot will meet required specifications.

The Next Lesson is: Rolling of Sheet and Plate Steel

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 8
Lesson 3
Time 1 hour

SUBJECT: Rolling of Sheet and Plate Steel

AIM (or purpose): To develop an understanding of the basic metallurgical practices in the making and finishing of steel

TEACHING AIDS: Film: Hot Rolling Steel Sheets, 8 mins., 16 mm, sound, U. S. Steel Corporation

EQUIPMENT: Film projector and screen

REFERENCES: Metals Handbook, 1948 Edition, American Society for Metals, Cleveland, Ohio
Nondestructive Testing-Introduction - PI-4-1, 1964, General Dynamics-Convair, San Diego, California
Information Sheet #18

I. PREPARATION (of the learner)
  A. Introduce film and point out the following highlights to be noted during the viewing of the film:
    1. The ragged ends of the plates and sheets as they are being rolled
    2. The removal of defects in the slab before final rolling
    3. The use of x-ray radiation to control the thickness of the sheet
    4. The control of the final temperature at the end of the rolling
    5. How some defects are removed at the mill and how some cannot be removed because their presence and location is not known
    6. The importance of temperature control if proper strength, welding and impact properties are to be obtained from the finished product

  B. Stress the importance of acquiring this related information and how it will benefit the student in the pursuit of knowledge in the field of radiography.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
"Hot rolling steel sheets"	Show the Film

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Have students discuss the control of end and edge defects:
   1. The cropping of the skelp to eliminate edge laminations
   2. The shearing of sheet strip before coiling

B. Discuss the removal of defects before final rolling.
   1. Defects may not be removed on thicker materials
   2. Areas of removal are leveled by subsequent rolling in thin sheet
   3. All defects may not be detected by the mill

C. Discuss the techniques of gauging thickness by radiation

D. Discuss the effect of poor finishing temperature on the steel:
   1. Wrong strength properties
   2. Poor welding properties
   3. Poor impact properties

E. Invite questions throughout discussion and reshow all or parts of film if necessary.

F. Pass out information sheet # 18 and discuss.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Oral Quiz

A. Why is it necessary to crop the edges and ends of rolled sheet and plate?

B. What is the result of improper control of the final rolling temperature?

C. Are all plates and sheets rolled from materials from which the defects have been removed?

D. Can improper final rolling temperature cause defects to occur in later fabrication?

Upon completion of test, discuss answers given, give help where needed

V. SUMMARY

A. Sheet and plate steel ends are cropped to remove laminations.

B. Grinders remove surface defects before final rolling.

C. Radiation emitting gauges are used to control the desired plate thickness as plate is being rolled.

D. Steel must be soaked before rolling to insure uniform temperature throughout the plate before rolling.

E. Temperature control during rolling insures proper strength, welding and impact properties

The Next Lesson is: The Structure of Metals

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 8
Lesson 4
Time 1.5 hours

SUBJECT: The Structure of Metals

AIM (or purpose): To outline the basic structure of metals and develop a thorough understanding of the subject

TEACHING AIDS: Prepared sketches on passout sheets showing the three basic metallic structures

REFERENCES: Elements of Material Science, L. H. Van Vlack, 1961, Addison-Wesley Publishing Company, Reading, Mass. Physical Metallurgy for Engineers, D. S. Clark, and W. R. Varney, 1962, D. Van Nostrand Company, Princeton, N. J.

I. PREPARATION (of the learner)

Explain why the knowledge of basic structure of metals is necessary information for the radiographer.
Point out that this information will be most helpful in interpreting x-ray films and in giving explanation of defects shown in the film.
Review again some of the defects of metals that are evidenced by x-ray film.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The metallic bond	1. Sketch a single plane view of a metallic structure. 2. Explain: a. The loosely held orbital electrons b. The electron cloud c. The forces holding the structure together 3. Relate the loosely held electron forces to the high electrical and thermal conductivity of metals.

II. PRESENTATION (continued)

Instructional Topics	Things to Remember to Do or Say
B. The crystalline structure or space lattice	1. Sketch the three basic metallic structures on the chalkboard. 2. Draw sketches and show the major slip planes in each structure. 3. Define yield point and ultimate strength in terms of bonding energies.
C. The metallic phases	1. Define the phase as a physically homogenous and distinct portion of a material system. 2. List some possible types of phases in metals such as: pure component, intermetallic compounds, solid solutions, etc. 3. Define the intermetallic compound and solid solution on chalkboard. 4. Use the example of ice tea and sugar to illustrate possible phases; liquid, solid (ice) and steam vapor. 5. Define and contrast the substitutional and interstitial solid solutions. Explain that substitutional solid solutions have limited effects on strengthening of metals. Point out that substitutional alloying is generally used to improve properties other than strength; such as corrosion resistance, better impact properties, ductility. Interstitial alloying is generally employed to increase tensile and yield strength. 6. Use the example of carbon in iron and copper in nickel to illustrate the two types of solid solutions. 7. Ask questions for understanding.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Have students explain the ice tea and sugar system in terms of the type of solution and the phases present from frozen to boiling.

B. Have students sketch the three basic metallic crystalline structures.

C. Ask the students to define an intermetallic compound, a substitutional solid solution, and an interstitial solid solution. Have the students draw sketches to illustrate the structures of each of the above phases.

D. Ask students to define "steel".

E. Review with the class the reason for the high electrical and thermal conductivity of metals.

F. Discuss with the class the yield point and untimate strength of a metal in terms of atom movements in the structure.

IV. TEST (final check on students' comprehension of material presented)

A. Suggested questions for a brief written test:
   1. List and sketch the three basic metal lattice structures.
   2. Define a phase.
   3. What are three types of phases found in metallic structures?
   4. What happens to the atomic structure when a piece of metal is yielded? Pulled into two pieces?
   5. What is steel?

B. Discuss correct answers with the class.

V. SUMMARY

Before advancing to the next lesson review the following points of this lesson.

A. The bonding between atoms determines the properties of the materials.

B. The properties of metals are determined by their crystalline structure. All metals have one of three basic types of crystalline structure: body centered lattice, face centered cubic, and hexagonal close pack.

C. The properties of a specific alloy system can be altered by suitable changes in the phases present in the system. These changes are generally accompanied by heat treatment.

The Next Lesson is: The Phase Diagram (Metallurgy)

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 8
Lesson 5
Time 2 hours

SUBJECT: The Phase Diagram (Metallurgy)

AIM(or purpose): To acquaint the student with the basic metallurgical principles

TEACHING AIDS: Copies of Iron-Carbon Diagram

REFERENCES: Elements of Material Science, L. H. Van Vlack, 1961, Addison-Wesley Publishing Company, Reading, Mass.
Physical Metallurgy for Engineers, D. S. Clark and W. R. Varney, 1962, D. Van Nostrand Co., Princeton, N. J.

I. PREPARATION (of the learner)

A. Introduce topic giving a thorough explanation of why this subject is important to the development of a radiographer.

B. Also show how this lesson will help one to understand the properties of metals and how they can be altered or tailored to fit a particular need.

C. Create discussion by explaining what properties are desirable in an automobile spring, a cutting tool, a pocket knife, coil spring, and baling wire.

D. Point out the difference between cast iron and steel and how raw material is altered to make cast iron or steel.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The phase diagram	1. Define the phase diagram as a graphical representation of temperature and composition of phases. Draw a typical diagram on the chalkboard.
	2. Explain the equilibrium conditions under which the diagram is constructed. a. All diagrams based on very slow temperature changes b. Diagrams reveal phases present at a given temperature c. They serve as reference to possible phases present in an alloy system.
	3. Draw a phase diagram of copper-nickel.
	4. Label and define coordinates.
	5. Define terminal phases as the pure component or liquid solubility phase.
	6. Define liquid phase as molten metal.
	7. Define the liquid plus solid phase field as the phase where solid metal floats in liquid.
	8. Define solid phase field as the phase below the melting point of all alloys.
	9. Draw phase diagrams of the Ag-Cu system.
	10. Define Eutectic as the reaction of a liquid that forms two or more different solid phases during cooling.
	11. Ask questions
B. The Iron-Carbon diagram	1. Sketch the iron-carbon diagram on chalkboard.
	2. Define Ferrite as iron with a maximum of 0.07% carbon content.
	3. Define Austenite as a body centered cubic lattice structure in iron at temperatures above 1, 333 Deg. F. or at room temperature in steel achieved by alloying with suitable elements. More ductile than alpha ferretic steel.
	4. Define the Eutectoid reaction as the reaction of a solid that forms two or more new solid phases during cooling.

As with Eutectic, the word Eutectoid can also refer to an alloy composition or structure associated with the reaction.

5. Carbide or Cementite is also called iron carbide; a normal constituent of annealed steels and cast iron. Strengthens steel but decreases ductility.
6. Explain the upper and lower critical temperatures between ferrite and austenite fields.
7. Define limits of steel as between 0.07% and 1.7% carbon content.
8. Define limits of cast iron as between 1.7% and 6.6% carbon content.
9. Explain the lower melting point of the Eutectic composition and explain its importance in casting practice. The eutectic temperature can be achieved with less expensive equipment because of the lower temperatures required. Eutectic composition contains 4.3% carbon.
10. Indicate the temperature ranges of melting for cast steel. (about 2,800 Degrees F.)
11. Ask questions

C. The phase transformation

1. Explain the transformation from one phase to another on heating or cooling through the transformation temperature:
   a. As temperature changes metal may go through a change because the structure at that temperature may be unstable.
   b. This phenomenon used to advantage to change properties of an alloy system.
   c. Example: Steel heated to transform structure to austenite; if quenched in oil the phase produced results in much higher strength.
   d. Alpha iron: The form of iron that is stable below 1,670 Deg. F., the temperature at which a change in phase occurs.

   - e. Gamma iron: The form of iron that is stable between 1, 670 Deg. F. and 2, 550 Deg. F.

2. Indicate the crystalline structure change in the transformation of austenite to ferrite by explaining that austenite is the high temperature body cubic centered structure (sketch) and ferrite is the FCC structure (draw sketch).
3. Elaborate on the temperature range of transformation of steel compositions above and below as well as the eutectoid composition.
   - a. Full transformation to austenite below eutectoid composition accomplished at 1, 650 Deg. F.
   - b. Above the eutectoid temperature the maximum required is 2, 065 Deg. F. at a carbon content of 1. 7%.
   - c. To achieve full hardness from heat treatment the temperature must produce a full austenitic structure.
4. Explain the martensite reaction on the chalkboard as the change from the austenitic structure (face centered cubic) at elevated temperature to the ferrite structure (body centered cubic) at low temperatures.
5. Define the properties of martensite:
   - a. strong
   - b. hard
   - c. tough

Ask and invite questions

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Have a student sketch a simple phase diagram of a system of components which are completely soluble in one another.

B. Ask group to explain various parts of the diagram.

C. Have another student sketch the iron-carbon diagram.

D. Request group members to label each phase field by its metallurgical name.

E. Have a discussion on the limits of the steel and iron ranges of composition.

F. Ask for comments on the difference in melting points of steel and cast iron.

G. Have each member explain the advantages and methods of using the diagram.

H. Ask and invite questions throughout the drill.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. Describe the composition of the following:
  1. Ferrite or alpha iron
  2. Austenite or gamma iron
  3. Cementite or carbide

B. Outline the composition limits of irons and steel.

C. Define a terminal phase.

D. What does the upper and lower critical temperature represent on the phase diagram?

E. What is a eutectic composition?

F. Sketch the iron-carbon diagram.

Check and discuss.

V. SUMMARY

A. The phase diagram is useful for determining changes in structure when the temperature or composition of the alloy is altered.

B. The iron-carbon system is the most important engineering alloy system.

C. The alteration of composition and temperature can produce a multitude of desirable properties.

D. The phase transformation is a result of changing the temperature of the system. The martensite transformation is the most widely used and most economical strengthening material used in engineering alloys.

The Next Lesson is: The Manufacture of Castings

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 8
Lesson 6
Time 2 hours

SUBJECT: The Manufacture of Castings

AIM (or purpose): To familiarize the student with the methods used to produce castings and the defects which can result from improper casting procedures

TEACHING AIDS: Sample castings with and without defects
Small casting with riser, runner, and sprue attached

REFERENCES: Cast Metals Handbook, American Foundrymen's Society, 1944, Chicago, Illinois
Physical Metallurgy for Engineers, D. S. Clark and W. R. Varney, 1962, D. Van Nostrand Co., Princeton, N. J.

I. PREPARATION (of the learner)

A. Introduce the subject and explain the importance of the information contained in this lesson pointing out that a knowledge of the origin of casting defects aids in their interpretation as they may be shown on radiographs.

B. Explain further that a good inspector should be able to discuss the nature of a casting defect and the alleged origin of it in the language of the foundryman.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The mold	1. Sketch a typical foundry mold and label the drag, the cope, cores, risers, and downsprue. 2. Define the function of the various parts of the mold. 3. Show the casting with all gates and risers still in place.

	4. Ask pertinent questions and invite discussion.
B. The pattern	1. Explain the function of the pattern and how it creates the shape of the casting in the mold. 2. Explain why the pattern is always larger than the final part: a. To allow for thermal expansion b. Allowing for surface defect removal without altering size of casting. c. Ask questions
C. The molding materials	1. Define the composition of the sand used for molding. 2. Explain the difference between a green and dry sand mold pointing out that green sand used wet is more economical than dry sand. Steam generated from wet sand causes little trouble on large castings. Scabs may be formed but can be avoided by skin-drying mold with gas flame. 3. Describe the process of ramming as the packing of sand around the pattern in making a sand mold. It is necessary to overcome the formation of voids, however, care must be exercised in the process to prevent the shifting of the pattern in the mold. 4. Ask questions
D. Pouring of the hot metal	1. Define metal fluidity explaining that it pertains to molten metal and its ability to flow as into a mold. 2. Explain why metals are poured 200 to 700 degrees above their melting temperatures: a. To prevent cold laps b. To allow thicker section of casting to form properly before metal solidification 3. Ask questions

E. Solidification	1. Explain the solidification in thin and thick sections of a mold stressing that metal must flow from thin to thick section of mold or vice versa and must not solidify prematurely. 2. Define "hot spots". 3. Ask questions
F. Casting defects	1. Define and illustrate the origin of: a. Porosity b. Dross c. Shrinkage cavity d. Misruns e. Cold shuts f. Cracks 2. Show the sample castings and defects discussing and explaining as each is shown.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Have a member of the group draw a cross section of a casting mold on the chalkboard.

B. Have another student draw in a simple pattern with all necessary openings.

C. Have still another label all the parts of the mold.

D. Ask participants to explain why the pattern cavity is larger than the final part.

E. Ask each individual student to explain the origin of the following defects: (Using a sketch for clarity if necessary)
   1. Porosity
   2. Dross
   3. Shrinkage cavity
   4. Misruns
   5. Cold shuts
   6. Cracks

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. Why is the pattern always larger than the final part ?

B. Do larger castings require higher pouring temperatures? Why?

C. What type of defect could occur if the pouring temperature was not high enough?

D. What type of defects can develop from the contraction or shrinkage of the metal on cooling?

E. What is meant by ramming a mold?

F. What type defect would occur from improper ramming?

Check and Discuss

V. SUMMARY

A. Proper design of mold can eliminate the formation of casting defects.

B. Pattern size allows for shrinkage that occurs when casting cools and solidifies.

C. Some molding materials are porous to allow escape of hot vapors and gases through the walls of the mold.

D. Castings with a wide thickness latitude can contain shrinkage cracks due to uneven cooling.

E. There are several types of casting defects, the more numerous being porosity and shrinkage.

The Next Lesson is: The Heat Treatment of Steel

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 8
Lesson 7
Time 2 hours

SUBJECT: The Heat Treatment of Steel

AIM (or purpose): To outline the operations which are employed in strengthening of steel

TEACHING AIDS: Sketch of iron-carbon diagram on pass out sheet (one for each class member)
Sample of normal, quenched and tempered steel strips
Samples of heat treat cracks in metal

REFERENCES: Elements of Material Science, L. H. Van Vlack, 1961, Addison-Wesley Publishing Company, Reading, Mass.
Physical Metallurgy for Engineers, D. S. Clark and W. R. Varney, 1962, D. Van Nostrand Company, Princeton, N. J.

I. PREPARATION (of the learner)

Use the following questions with explanation to introduce this lesson:

A. What happens when a piece of metal is heated to red hot and immersed in water?

B. What process has been used on your pocket knife blade to give it proper temper?

C. Why is this process sometimes used on welds?

D. Why do some metals crack when subjected to this type treatment?

E. After heating and cooling, what would happen if the piece was reheated to a lower temperature?

F. Explain that this information will assist the radiographer in understanding the cause of equipment failure due to a lack of heat treatment or because of improper heat treatment.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The iron-carbon diagram	1. Sketch the iron-carbon diagram on the chalkboard. 2. Call to the students attention that this is an equilibrium diagram. 3. Review the phase change of cooling from the austenite phase to the ferrite region. 4. Explain the formation of pearlite in slow cooling when cooled slowly from critical temperature,it is a direct transformation product from Austenite. Pearlite is the eutectoid of iron and iron carbide and it resembles mother-of-pearl when viewed under a microscope. It consists of alternate layers of lamellae of iron and cementite and contains 0.33% carbon. 5. Explain the expansion of steel in the transformation change due to the difference in volume of the two phases.
B. The martensite reaction	1. Define the martensitic structure as a body centered tetragonal. Martensite is the hardest of the transformation products of austenite. When carbon content exceeds 0.5% tetragonality of the crystal structure is observed. Martensite is not an equilibrium phase. 2. Explain the distortion of the ferritic structure by the wedging action of the supersaturated carbon. 3. Describe how martensite is formed by rapid cooling to prevent the transformation to pearlite. Martensite in quenched steel has needle-like patterns. This structure in steel is obtained by direct transformation from austenite, by rapid cooling to prevent upper transformation products.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The iron-carbon diagram	1. Sketch the iron-carbon diagram on the chalkboard. 2. Call to the students attention that this is an equilibrium diagram. 3. Review the phase change of cooling from the austenite phase to the ferrite region. 4. Explain the formation of pearlite in slow cooling. When cooled slowly from critical temperature it is a direct transformation produce from AUSTENITE. Pearlite is the eutectoid of iron and iron carbide and it resembles mother-of-pearl when viewed under a microscope. It consists of alternate layers of lamellae of iron and cementite and contains 0.33% carbon. 5. Explain the expansion of steel in the transformation change due to the difference in volume of the two phases.
B. The martensite reaction	1. Define the martensitic structure as a body centered tetragonal. Martensite is the hardest of the transformation products of austenite. When carbon content exceeds 0.5% tetragonality of the crystal structure is observed. Martensite is not an equilibrium phase. 2. Explain the distortion of the ferritic structure by the wedging action of the supersaturated carbon. 3. Describe how martensite is formed by rapid cooling to prevent the transformation to pearlite. Martensite in quenched steel has needle-like patterns. This structure in steel is obtained by direct transformation from austenite, by rapid cooling to prevent upper transformation products.

	4. Define the martensite start and finish temperatures. 5. Describe the properties of martensite before tempering. It has the maximum hardness and strength of any decomposition product from austenite in steels.
The tempering process	1. Define the term "tempering" (sometimes called "drawing") as a treatment below the lower critical temperature below the lower critical temperature followed by any desired rate of cooling. Example: One percent carbon steel after quenching in water from 1, 450 degrees F. is extremely hard and brittle. Tempering at between 200 and 400 degrees F. results in slight loss of hardness and a great increase in toughness. 2. Explain the effect of tempering on the structure of martensite, pointing out that quench cracking may be prevented and the steel is [illegible]s susceptible to distortion. 3. List some desirable properties of tempered martensite.
Cracking caused by heat treatment	Show samples containing heat treating cracks. 1. Discuss the stresses caused by the martensite reaction. 2. Explain the quench crack and its formation -- show sample. 3. Draw a chalkboard sketch of the stress that develops in the transformation to martensite. Demonstrate: 1. Display three strips of steel about 1/4" x 1/4" x 12" long. One should be heated and quenched, one tempered and one without heat treatment. 2. Explain the properties of each steel strip and how they differ.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Have students explain by a chalkboard sketch the formation of pearlite by the slow cooling of steel from the austenite to the ferrite region.

B. Have students explain by a chalkboard sketch the formation of martensite by rapid cooling from the austenite region.

C. Ask students to elaborate on the transformation of martensite in terms of the volume change and stresses created. Have them contrast the martensite and pearlite transformation.

D. Ask the students to list the desirable properties of tempered martensite.

IV. TEST (final check on students' comprehension of material presented)

A. Explain the martensite reaction using a sketch of the iron-carbon diagram.

B. What is the purpose of tempering the martensitic structure?

C. Explain how stresses are created by the martensitic reaction. Account for the stresses from both transformation and cooling.

D. Sketch the crystalline structure of steel in the austenite range and after transformation to martensite.

E. List three desirable properties of tempered martensite.

Discussion of questions by the group after the test

V. SUMMARY

A. Heat treatment of steel can both prevent and cause equipment failure.

B. Heat treatment can remove stresses that were formed in a weldment during the welding process.

C. Metal properties can be changed to fit their applications by heat treatment.

D. Some of these properties are: ductility, elasticity, malleability, toughness, and brittleness.

The Next Lesson is: Visit to a Foundry

INSTRUCTOR'S LESSON PLAN
Field Trip

Unit 8
Lesson 8
Time 6 hours

SUBJECT: Visit to a Foundry

PURPOSE: To permit the students to observe the pouring, control and inspection of cast metals

MATERIALS: Film badges, dosimeters, safety hats, and safety glasses

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I. PREPARATION (of the learner)

A. Outline purpose of visit and stress need to observe all safety precautions.

B. The students should also be coached to carefully observe and make notes of the following:
   1. Preparation of the sand for molds
   2. Preparation of the molds (ramming)
   3. Placement of the chaplets and chills
   4. The flow paths of the molten metal
   5. Pouring of the molten metal
   6. The removal of the casting from the sand (shakeout)
   7. Inspection of the finished casting

II. PRESENTATION (of the information)

A. Issue safety instructions to be followed while in the plant stressing the need for gentlemanly behaviour.

B. Make the tour only under the guidance of a designated foundry employee and the instructor.

III. APPLICATION

A. After completing the trip, ask the students to discuss:
   1. Why the sand is given so much care and testing.
   2. Why the molds are larger than the final part.
   3. The purpose of chaplets and chills in mold preparation.
   4. Why the metal is allowed to flow back to the surface of the mold during pouring.
   5. How defects can result from removing the casting from the sand while the metal is still red hot.

    6. The inspection techniques used by the foundry.

B. Invite questions and discuss unusual procedures noted.

IV. TEST

NOTE: Written Test

Write a brief report on the observations made during the field trip covering all aspects of foundry operation from preparation of molding materials to the inspection of the finished product.

V. SUMMARY

A. A casting is the result of many closely controlled processes and steps.

B. Misalignment of molds can cause casting defects.

C. Extra metal is necessary when pouring a mold to allow for shrinkage during the cooling process.

D. Final inspection of castings may include hardness tests and a variety of other types of nondestructive explorations.

E. A ladle analysis is generally made before castings are poured.

The Next Lesson is: The Metallurgy of Welding

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 9
Lesson 1
Time 2 hours

SUBJECT: The Metallurgy of Welding

AIM (or purpose): To provide information and develop an understanding of the reactions which occur during the welding process and their effect on the weld structure

TEACHING AIDS: Iron carbon diagram chart (pass out sheet for each class member)
Sample electrodes with coatings
Sectioned and etched welds

REFERENCES: Welding Metallurgy, G.H. Linnert, 1965, American Welding Society, New York, N.Y.
Physical Metallurgy for Engineers, D. S. Clark and W.R. Varney, 1962, D. Van Nostrand, Princeton, N.J.

I. PREPARATION (of the learner)

A. Introduce the lesson subject by asking selected basic questions to start short discussions. The following questions should be used to help lead the class into a discussion of the lesson:
   1. Have any of you ever done any welding?
   2. What is welding?
   3. How many different types of welding processes do you know of?

B. Point out that a general knowledge of welding processes is necessary to understand the cause of welding defects and a radiographer must have this understanding in order to intelligently perform his work.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The structure of the weld 1. The weld deposit 2. The fusion zone 3. The heat affected zone 4. The parent metal	1. Review the metallurgy of cast steel. 2. Draw a sketch of a typical weld and label the different zones. 3. Show samples of actual welds and explain pertinent features.

B. The molten metal shield 1. Inert gases 2. Electrode coatings a. Slagging coatings b. Volatile coatings 3. Suberged arc flux	1. Show sample electrodes and discuss: a. The degasification of the molted metal b. Protection of the molten metal from the atmosphere c. Reduction of impurities in the weld puddle d. Addition of alloys to the weld from slags and flux
C. Cooling of the weld puddle (solidification)	1. Draw a sketch of a typical weld and an iron-carbon diagram on the chalkboard. 2. Associate the structure of the weld with phases of the iron-carbon diagram. 3. Describe the effects of cooling on warpage and residual stresses in welds of steel.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Ask students to sketch a typical weld profile on the chalkboard and label each metallurgical zone.

B. Have students plot the changes in volume and explain the stresses developed in the solidification and cooling of welds.

C. Discuss with student participation the control of the final structure of welds in steel by proper heat control, i.e., preheat, postheat and interpass temperature.

D. Have the students explain the purpose of electrode coatings, gas shielding and fluxes.

IV. TEST (final check on students' comprehension of material presented)

A. Suggested questions for written test:
   1. Outline the purpose of the coating on welding electrodes.
   2. Describe the source and action of the stresses developed in the cooling of the weld deposit in a weld of carbon steel.
   3. Sketch a typical weld and label each distinct metallurgical zone.
   4. What is the purpose of preheat and postheat in the welding process?
   5. How do the slag and flux shields differ from that produced by gases?
   6. What are the advantages of the slagging shields?

B. Check the test with the class, making sure each person has the correct answers.

V. SUMMARY

The structual soundness of a weldment depends upon: proper selection of weld electrode, controlled metal temperature, proper joint preparation, removal of foreign materials from weld, prevention of oxidation of the weld, and joint, control of effects of expansion, contraction and warpage and environmental factors.

The Next Lesson is: The Welding and Joining Processes

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 9
Lesson 2
Time 2 hours

SUBJECT: The Welding and Joining Processes

AIM (or purpose): To develop an acquaintance with the various approved methods and processes of joining metals

TEACHING AIDS: Posters and charts
Samples of various types of welds
Samples of soldering

REFERENCES: Welding Metallurgy, G.H. Linnert, 1965, American Welding Society, New York, N.Y.

I. PREPARATION (of the learner)

A. Introduce the topic and briefly describe the radiographer's interest in the proposed subject.

B. To arouse attention and create interest discuss and outline the difference between welding and soldering, also point out the advantages of welding a structure instead of bolting it together, and whether the welding assembly is considered as sound structurally as one that has been made by the forging process.

C. In addition, explain that the lesson should help the radiographer in the interpretation of radiographs. Radiographic interpretation of weldments depends to a significant degree upon the radiographers understanding of the welding or joining process. For this reason, the radiographer should be able to assure the welder that he (the radiographer) knows enough about the welding process to be able to render sound judgements.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Fusion welding 1. Shielded metal arc (coated electrode) 2. Inert gas metal arc 3. Submerged arc 4. Tungsten inert gas arc 5. Gas welding 6. Thermit welding	1. Explain and illustrate the process of fusion and how it is employed to join metals. 2. Give a brief description of each of the various fusion processes: a. Coating on the electrode protects weld puddle from oxidation . b. Inert gas, usually argon, displaces air around weld puddle. c. Air is submerged beneath granular coating for protection from air. d. Tungsten inert gas arc - heat generated by arcing between it and the material being welded. Tungsten does not melt during process. e. Acetylene and Oxygen furnish heat in gas welding. f. In Thermit welding aluminum and iron powder are mixed and burned to give off heat up to 5,000° F. for welding. 3. Discuss the method of heat generation for each method. 4. Outline the purpose of shielding the molten weld metal from air contact thereby preventing oxidation. 5. Show sample welds of each method. 6. Explain the advantages and disadvantages of each method.
B. Electric resistance welding: 1. Spot and seam welding 2. Flash welding 3. Induction welding	1. Explain and discuss the method of heat generation in electrical resistance welding. 2. Explain the contact of mating parts during and after the heating cycles. 3. Explain the advantages and disadvantages of the processes: a. High initial cost of equipment is a disadvantage. b. Results easily reproduced an advantage.

    c. Speed of production also is an advantage.

C. Solid phase welding
    1. Ultrasonic welding
    2. Diffusion bonding
    3. Forge welding
    4. Pressure welding

1. Explain the process of diffusion, i. e., the movement of atoms across weld interface.
2. Describe the methods of creating a diffusion bond.
3. Explain the advantages and disadvantages of the listed group of welding processes:
    a. Limited to thin materials
    b. Very accurate control needed for good welds
    c. Entrapped oxides remain in weld
    d. No filler metal needed
    e. No heat needed for ultrasonic method
    f. Heavy forge equipment unnecessary for ultrasonic diffusion, and pressure welds

D. Liquid to solid joining or soldering

1. Explain and illustrate the wetting of a solid metal with a molten metal:
    a. This process is sometimes called "tinning". Specimens to be joined are first dipped in or coated with molten solder.
    b. Soldering is widely used in developing electrical circuitry.
    c. Galvanized materials such as root gutters are also joined by soldering.
    d. Household appliances usually have some soldered joints.
2. Give some additional examples where soldering is applicable.
3. Explain the advantages and disadvantages of the method.
4. Show samples of soldering and explain.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)
    A. Suggest that students describe the fusion joining process.

B. Have group explain the origin of the heat in the various arc welding processes.

C. Request a thorough discussion and explanation of heat generation in the electrical resistance welding methods.

D. Ask class for examples of applications using the various methods discussed. Have members justify their choice.

E. Have class identify the type of welding used to join each of the samples exhibited in the classroom.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What are the four major classifications of metal joining techniques?

B. What is the purpose of the gas or slag shield of the molten weld puddle?

C. What is the nature of the bond between the parent metal and solder in the solder-type joint?

D. Compare the advantages and disadvantages of:
  a. The shielded metal arc weld
  b. The inert gas metal arc weld

E. Why are the electrical resistance methods used primarily for production line work? Check and discuss.

V. SUMMARY

A. Fusion methods of welding are the types that account for a major part of industrial radiography work. They include shielded metal arc, inert gas metal arc, submerged arc, tungsten inert gas arc, acetyline gas, and Thermit welding processes.

B. Another widely used method is the electric resistance welding method which includes spot and seam welding, flash welding and induction welding.

C. Solid phase welding usually precludes the use of bonding metal and includes ultrasonic welding, diffusion bonding, forge welding, and pressure welding.

D. Liquid to solid joining is more commonly called soldering.

The Next Lesson is: The Weld Profile

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 9
Lesson 3
Time 1 hour

SUBJECT: The Weld Profile

AIM (or purpose): To develop knowledge and understanding of the component parts of a weld and welding terminology in general

TEACHING AIDS: Sample weld sections
Sample steel plates prepared for welding

REFERENCES: Welding Metallurgy, G.H. Linnert, 1965, American Welding Society, New York, N. Y.
Information Sheet #19
Test

I. PREPARATION (of the learner)

A. Explain the importance of the lesson and how it will help the radiographer to properly interpret radiographs of weldments, the radiographer must know the structure of a weld, its components and correct welding terminology if he is to have the confidence of his associates.

B. The welder will naturally have greater respect for the radiographer when discussing detected weld defects if the radiographer can converse in the language of the welder and make a professional diagnosis of the defects.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The fillet weld 1. Width 2. Throat 3. Toe 4. Root 5. Face	Use an overhead projector if transparencies have been prepared. If not, make chalkboard sketch as follows: 1. Draw a sketch of a typical fillet weld on the chalkboard.

	2. Label parts. 3. Explain the method of measuring the various dimensions. 4. Draw sketches of dimensionally correct and incorrect fillet welds. 5. Ask questions.
B. The butt weld 1. Groove 2. Groove angle 3. Root 4. Face 5. Root face 6. Root opening 7. Backing strips	1. Draw a sketch of a typical butt weld. 2. Describe and sketch the single and double groove butt welds 3. Label the parts of the welds. 4. Explain the methods of determining the various dimensions of butt welds. 5. Explain the purpose of the groove angle, the root opening, and the root face. 6. Sketch a backing strip in place on a single groove butt weld. 7. Explain the purpose of the backing strip. 8. Review welds and terminology throughout the discussion. 9. Ask questions.
C. Weld passes or layers 1. Stringer or root	Refer to information sheet # 19 and to the first illustration on the chalkboard The root pass is probably e most important and most troublesome pass. 1. Complete penetration of this pass is necessary. 2. A root pass can contain: incomplete penetration, burn through, icicles, incomplete fusion, slag and cracks. Illustrate these on chalkboard during discussion.
2. Hot pass	A hot pass follows the root pass. 1. Some defects found in the root pass can be eliminated with a hot pass. 2. Lack of fusion, slag and cracks are sometimes found in a hot pass.

3. Filler passes	Filler passes follow the hot pass.
4. Crown or reinforcement pass	The crown is the top or final pass and some crown defects include, undercut, and lack of form in that some are concave or convex.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Pass the sample plates and welds among the students for examination.

B. Ask a student to:
   1. Sketch a fillet weld on the chalkboard
   2. Label the various parts of the fillet weld
   3. Sketch a single groove butt weld on the chalkboard
   4. Label the parts of the butt weld

C. Ask for the definition and purpose of the following parts of the but weld:
   1. The groove opening
   2. The root face
   3. The backing strip
   4. The root opening

D. Request discussion and definition of root, hot fillet, and crown passes or layers.

E. Discuss possible flaws sometimes found in these passes and invite questions.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. Sketch a fillet weld and name the parts.

B. Sketch a single groove buttweld and name the parts.

C. Explain the purpose of:
   1. The root opening
   2. The root face
   3. Backing strips

D. Give test on Information Sheet #20

Check and discuss

V. SUMMARY

A. An understanding of the weld profile is essential when radiographs of weldments are being interpreted and discussed.

B. Fillet weldment description includes: toe, root, face, throat and width.

C. Butt weldments are described by: root, root opening, face, face opening, groove, groove angle, backing strips.

D. Weld passes include: root, hot pass, filler passes and crown.

The Next Lesson is: Weld Defects

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 9
Lesson 4
Time 2 hours

SUBJECT: Weld Defects

AIM (or purpose): To assist the student in acquiring the ability to recognize the defects found in weldments and to be aware of the capabilities of radiography to detect these defects

TEACHING AIDS: Samples of defective welds
Film of defective welds
High intensity film viewer

REFERENCES: Nondestructive Testing Handbook, 1963, Society for Nondestructive Testing, Evanston, Illinois
Information Sheet #19

I. PREPARATION (of the learner)

A. Introduce this lesson by discussing the following questions giving the correct answers.

1. Can radiographic techniques be used to find all defects in welds? Why?
2. What type of defects can be detected?
3. Why is it important for the radiographer to know the limitations of the technique?

B. Explain that the information presented in this lesson will help to interpret radiographs correctly. Point out that the interpretation should indicate the type of defect shown in the radiograph as some defects are more serious than others. For example, a crack in a weld would be more important than a gas bubble.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Profile defects	1. Use overhead projector or draw a chalkboard sketch of fillet and

1. Undercutting 2. Excessive reinforcement 3. Lack of penetration 4. Concavity	butt welds showing each type of defect. 2. Refer to information sheet #19. 3. Illustrate the origin of each type defect. 4. Compare the severity of each defect. 5. Illustrate the appearance of the defect image on radiographic film. 6. Show sample film.
B. Structural defects 1. Porosity 2. Slag inclusions 3. Incomplete fusion 4. Cold lapping 5. Cracking a. Longitudinal b. Transverse c. Crater d. Underbead	1. Draw a chalkboard sketch of each type defect. 2. Illustrate the origin of each type defect. 3. Compare the severity of the defects. 4. Illustrate the appearance of the defect indication on radiographic film. 5. Show sample film-explain and discuss. 6. Explain the limitation of radiography in detecting certain types of defects.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Have students sketch welds with the four types of cracks found in welds.

B. Ask students to explain the origin of the cracks.

C. Ask the students to define the limits of radiography for detection of weld defects.

D. Have the students identify defects on the sample film.

E. List the following defects in terms of their severity:
1. Slag inclusions
2. Porosity
3. Concavity
4. Cracking

IV. TEST (final check on students' comprehension of material presented)

A. List three types of profile defects.

B. List three types of structural defects.

C. What is the cause of slag inclusions in a weld?

D. Show the four types of cracks found in welds by sketches.

E. State what conditions must exist for a weld defect to be found by radiography.

Check and discuss

V. SUMMARY

A. Welding defects can be either structural or profile defects.

B. Profile defects are usually visible except if they are inside a small diameter pipe.

C. Structural defects can be either visible or invisible, such as cracks in the weld or the base metal or extending into both.

The Next Lesson is: Field Trip to Observe Welding Procedures and Operations

INSTRUCTOR'S LESSON PLAN
Related Technical Information
Field Trip

Unit 9
Lesson 5
Time 6 hours

SUBJECT: Welding Procedures and Operations

AIM (or purpose): To observe joint preparation, welding, and inspection of welded assemblies

MATERIALS: Film badges, dosimeters, safety glasses, hard hats

REFERENCES: Information Sheet #21

I. PREPARATION (of the learner)

A. Introduce subject of trip and its purpose requesting students to carefully observe the following procedures:
   1. Inspection of materials prior to fabrication
   2. The techniques of joint preparation
   3. The various types of welding processes
   4. Methods of marking for inspection identification
   5. Documentation of inspection and quality control

B. Read instructions to be followed while on field trip from Information Sheet #21, and invite any questions regarding the subject trip.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Tour a fabrication shop which maintains its own inspection department.	Stress the need for gentlemanly behaviour.
B. Students are to make notes as necessary.	

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. After returning from the trip, ask the students to describe:

1. Methods employed to inspect materials before beginning fabrication
2. The various types of welding joints used by the fabricator
3. All welding techniques and equipment employed by the manufacturer
4. The observation of weldments at the final inspections
5. The preparation of documents relative fabrication and inspection

B. Discuss any unusual observations made while touring the shop and invite questions.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. Name and briefly describe the various welding processes you observed on the field trip.

B. How does the inspector know which welder or welders worked on a particular weldment?

C. Why do two or more welders work simultaneously on the first pass of a thick walled, large diameter pipe joint?

D. Describe briefly the joint preparation of a weldment.

E. Name some methods of quality control observed on this field trip.

Check and discuss

V. SUMMARY

A. Joint preparation

B. Types of passes

C. Inspection procedures and aids

D. Documentation and quality control

The Next Lesson is: Multiple Exposure Pipe Radiography

EXPERIMENT SHEET
Multiple Exposure Pipe Radiography

Unit 9
Lesson 6
Time 4 hours

SUBJECT:

Inspection of a circumferential pipe weld using the multiple exposure technique

NOTE: Instructor performs all operations

INTRODUCTORY INFORMATION:

Inspection of circumferential pipe welds may be accomplished using several techniques of exposure. The double wall multiple exposure technique is used when access is not available to the inside surface, or the diameter to thickness ratio is too small to achieve satisfactory sensitivity. The length of weld which can be inspected on each exposure is limited by the change in metal thickness and change in film-focal distance around the pipe. With proper procedures, satisfactory radiographs can be obtained from one side.

MATERIALS AND EQUIPMENT:

Gamma ray source and exposure facilities
Film cassettes and film
Gamma ray survey meter
Pipe samples
Penetrameters, lead numbers, and shims
Chart of diagnostic film lengths
Dark room facilities

PROCEDURE:

A. Single load film cassettes with selected film and lead screens.

B. Transport film, gamma ray exposure device, and accessories to exposure site.

C. Determine the diagnostic length of each exposure.

D. Divide the pipe circumference into segments equal to the diagnostic length.

E. Attach the exposure tube to the pipe opposite to the first segment to be exposed.

F. Position the tube to the edge of the weld and directly opposite to the center of the segment to be exposed.

G. Determine the extent of the weld reinforcement and select shims of this added thickness.

H. Select a penetrameter which will indicate 2-2T sensitivity on the pipe wall if its equivalent 2T penetrameter could be placed on the inside.

I. Attach penetrameters on shims to the pipe at the center and the extreme end of the segment selected for exposure.

J. Attach lead numbers to the pipe segment to identify the exposure and to facilitate location of defects.

K. Mark the location of the lead numbers on the surface of the pipe.

L. Attach the film cassette to the outside of the pipe.

M. Position the film neatly over the segment to be inspected.

N. Secure the film tightly to the pipe with tape or elastic bands to insure intimate contact of film and screens.

O. Attach a large letter "B" to the back side of the film cassettes where it will not interfere with the image of the weld line.

P. Calculate the exposure time required to produce a density not less than 1.5 on the greatest thickness or more than 3.3 on the least thickness.

Q. Attach the source tube to the camera and extend the control cables to a convenient location for operation.

R. Energize the survey meter, wait for warm up, and zero meter.

S. Extend source and expose for the required time.

T. Retract source into camera and survey camera to insure the safe return of the source. Lock source in camera.

U. Remove film, move source tube to next segment of the pipe, and repeat steps F through T until all segments have been exposed.

V. Develop all film for 5 minutes at 68°F. fix, wash, and dry.

W. View film for defects; prepare report of exposure and weld quality.

CONCLUSIONS:

A. Penetrameters are required at two locations on the pipe because the ____________ path is not of the same thickness and the _________ distance is different at these two locations.

B. The image of the letter "B" may appear on the radiograph due to __________. This can be eliminated by ___________.

C. The sensitivity at the edge of the film is ______________ than the center of the film due to the effect of ____________________ radiation.

D. The density of the film at the edge of the film is ______________ than in the center because of the difference in ___________ ________________ distance.

The Next Lesson is: The Effect of Focal Distance

EXPERIMENT SHEET
The Effect of Focal Distance

Unit	9
Lesson	7
Time	4 hours

SUBJECT:

The effect of changing the film-focal distance on the distortion of the image and the sensitivity of the film.

NOTE: Instructor performs all operations

INTRODUCTORY INFORMATION:

The degree of sharpness of an image depends on the size of the source and the distance between the source and the film. When the source is not a point, the case in all radiographic equipment, the image is distorted because each point in the source forms its own image. The overlapping of these images form a halo around the central image which is called penumbra. The penumbra distorts defects and the small holes of the penetrameter resulting in loss of definition. These effects can be reduced by increasing the film-focal distance and making use of the basic laws of mathematics.

MATERIALS AND EQUIPMENT:

Gamma ray (or x-ray) source and exposure facilities
8" x 10" film cassettes and film
Gamma ray survey meter
6" x 8" steel plate, 1/2" to 3/4" thick
Penetrameters and lead numbers
Dark room facilities

REFERENCES:

Information Sheet #7 Nomogram of Geometrical Unsharpness

PROCEDURE:

A. Single load film cassettes with selected film and lead screens.

B. Select penetrameters for 1/4" to 1 1/4" thickness in 1/8" steps.

C. Place the film on a lead sheet or exposure table.

D. Place the steel plate on the film and position in the center of the film.

E. Position the penetrameters on the plate in two neat rows in the center of the plate. Separate slightly and arrange in sequential order.

F. Attach lead number for identification. Avoid placing identification where it will obstruct the image of the penetrameters or plate edge.

G. Align source tube end directly over the center of the plate at a film – focal distance 5 times the thickness of the plate.

H. Calculate the exposure time required to produce a density of 1.8 to 2.2.

I. Attach the source tube to the camera and extend the control cables.

J. Energize the survey meter, wait for warmup, and zero meter.

K. Extend source and expose as required.

L. Retract source, survey, and lock source in camera.

M. Repeat steps C through L using 7, 10, 15 and 20 times the thickness of the plate for a film – focal distance.

N. Develop all film for 5 minutes at 68 F. Fix, wash and dry.

O. Examine film on viewer.

P. Record the minimum penetrameter sensitivity for each focal distance.

Q. Measure the geometric unsharpness of the plate dimensions and record for each focal distance.

R. Determine the expected geometrical unsharpness from the nomograms.

CONCLUSION:

A. The minimum sensitivity attained at a D/T of 7 is ______________.

B. A 2-2T sensitivity was observed at a D/T of ___________ and above.

C. List the values obtained for geometrical unsharpness:

D/T	Actual Measurement	From Nomogram
5	____________	____________
7	____________	____________
10	____________	____________
15	____________	____________
20	____________	____________

D. The measured value of geometrical unsharpness ____________ with that taken from the nomogram.

E. To improve radiographic sensitivity the film — focal distance is ____________.

The Next Lesson is: Double Pipe Radiography.

EXPERIMENT SHEET
Double Wall Pipe Radiography

Unit	9
Lesson	8
Time	3 hours

SUBJECT:

Inspection of welds in small diameter pipe using the double wall method of exposure to produce an image of both walls.

NOTE: Instructor perform all operations.

INTRODUCTORY INFORMATION:

When the outside diameter of a pipe is less than about four inches, inspection of welds can be accomplished by exposing both walls of the pipe to produce an elliptical image of the weld. Two exposures are required to achieve 100% coverage using this technique.

MATERIALS AND EQUIPMENT:

Gamma ray source and exposure facilities
Film cassettes and film
Gamma ray survey meters
Penetrameters, lead numbers, and shims
Welded pipe samples 4" or less
Dark room facilities

REFERENCES:

Information Sheet #22

PROCEDURE:

A. Single load film cassettes with selected film and lead screens

B. Transport equipment to exposure site.

C. Determine the outside diameter of the pipe.

D. Position source tube to expose the weld.

E. Locate source tube to the side of the weld about 30 degrees from the centerline of the weld.

F. The film to focal distance should be at least seven times the outside diameter of the pipe.

G. Determine the extent of weld reinforcement and select a shim of this added thickness.

H. Select a penetrameter which will indicate 2-2T sensitivity on the total thickness of both walls.

I. Attach the penetrameter, on a shim, to the pipe on the source side.

J. Place penetrameter directly in line with the source tube end on the opposite side of the weld from the 30 degree offset with the long axis parallel to the pipe.

K. Attach a film cassette to the pipe.

L. Attach the film to the pipe opposite to the source tube. The film should not be wrapped to the pipe but should remain flat and tangent to the pipe, perpendicular to the centerline of the exposure.

M. Position film allowing for the throw of the shadow of the weld. About two inches overlap of the weld on the source offset side is sufficient.

N. Attach lead numbers to the film for identification of the exposure.

O. Mark the point of tangency of the film to facilitate location of defects.

P. Calculate the exposure time required to produce a density not less than 1.5 nor more than 3.3.

Q. Attach the source tube to the camera and extend control cables.

R. Energize the survey meter, wait for warmup, and zero meter.

S. Extend source and expose the required time.

T. Retract the source into the camera, survey, and lock camera.

U. Repeat the entire operation to achieve a second exposure at 90 degrees to the first exposure.

V. Develop film for 5 minutes at 68 F. Fix, wash and dry.

W. View film for defects, prepare reports.

CONCLUSIONS:

A. The equivalent single wall penetrameter sensitivity of this radiographic tehcnique is ______________.

B. Two exposures are required for 100% coverage because ______ ____.

C. The source is offset from the weld to prevent the image of the top _________________ from obscuring the image of the bottom ________________.

D. The pipe diameter is used as a basis for determining the _________ __________ distance in order to obtain a ________ image.

The Next Lesson is: Panoramic Pipe Radiography

EXPERIMENT SHEET
Panoramic Pipe Radiography

Unit 9
Lesson 9
Time 4 hours

SUBJECT:

Inspection of a circumferential pipe weld using the panoramic exposure technique

NOTE:

Instructor performs all operations

INTRODUCTORY INFORMATION:

Inspection of circumferential pipe welds may be performed using several techniques of exposure. The panoramic technique produces rapid reliable results when access is available to the internal surface of the pipe and the diameter to thickness ratio is sufficient to permit the necessary film — focal distance. The advantages of the panoramic technique are, exposure through a single wall, uniform film-focal distance, and one exposure for an entire weld circumference.

MATERIALS AND EQUIPMENT:

Gamma ray source and exposure facilities
Film cassettes and film
Gamma ray survey meter
Penetrameters, lead numbers, and shims
Pipe samples
Dark room facilities

PROCEDURE:

A. Single load film cassettes with selected film and lead screens.

B. Transport film, gamma ray exposure device, and accessories to exposure site.

C. Position exposure tube end at the exact inside center of the pipe in line with the weld.

D. Select a penetrameter which will indicate 2-2T sensitivity on the pipe wall if its equivalent 2T penetrameter were placed on the outside.

E. Determine the extent of the weld reinforcement buildup.

F. Select a shim equivalent to the amount of weld reinforcement.

G. Place a penetrameter, on a shim, on the outside surface of the pipe adjacent to the weld with the long axis parallel to the pipe axis.

H. Attach lead numbers to the outside circumference of the pipe on the opposite side of the weld from the penetrameter.

I. Place numbers in increasing sequential order every six inches of circumference of the pipe.

J. Mark the location of the numbers in crayon on the exterior of the pipe.

K. Prepare and attach an identification code made from lead numbers and letters.

L. Attach the film cassettes to the exterior of the pipe.

M. Position the film neatly over the weld with approximately 1 1/2" overlap of film.

N. Secure film tightly to the pipe to insure intimate contact of film and screen and a minimum distance between the pipe and cassette

O. Calculate the exposure time required to produce a density not less than 1.5 on the greatest thickness and no more than 3.3 on the least thickness.

P. Connect exposure tube to the gamma ray camera.

Q. Extend control cables of gamma camera to a convenient location for operation.

R. Energize the survey meter, wait for warm up, and zero meter.

S. Unlock the gamma camera and extend source to exposure position. Expose film for the required time.

T. Return source to camera, survey to insure safe return, and lock source in camera.

U. Remove film from pipe, develop for 5 minutes at 68 F. fix, wash, and dry.

V. View film for defects. Prepare report of exposure and weld quality.

CONCLUSIONS:

A. Only one penetrameter is required to insure sensitivity because the ______________ is the same for all film.

B. The penetrameter will indicate 2% sensitivity of the __________ thickness through a total metal path equal to the _____________ thickness.

C. The penetrameter size used for this exposure did not correspond to the measured plate thickness because the penetrameter was placed on a shim equal in thickness to the weld ____________.

D. Sequential numbering of the pipe surface is performed to enable the inspector to determine the exact ___________ of defects.

The Next Lesson is: Radiography Film Interpretation (Welds)

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 9
Lesson 10
Time 2 hours

Note to Instructor: This is a practice lesson and time should be provided each week for practice on this material

SUBJECT: Radiography Film Interpretation (Welds)

AIM (or purpose): To acquaint the student with the fundamentals of weld film interpretation

TEACHING AIDS: Film viewer
Reference Radiographs of Steel Welds, ASTM E-99, American Society for Testing and Materials, Philadelphia, Pa.

MATERIALS: Sample welds
Sample film

REFERENCES: Nondestructive Testing Handbook, Volume I, Society for Nondestructive Testing, 1963, Evanston, Illinois

I. PREPARATION (of the learner)

Explain that knowledge of the theory of image formation cannot be substituted for experience in welding control. The radiographer must be able to explain each indication found on the film, and be able to differentiate the nonrelevant indications from those of consequence. This lesson is calculated to help the student to more fully understand the theoretical explanation of various defects and to assist him in gaining valuable experience in film interpretation.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Weld defects	1. Sketch a cross section of a butt weld containing slag inclusions.
1. Slag inclusions	
2. Lack of penetration	2. Sketch a density profile corresponding

3. Porosity 4. Cracks 5. Lack of fusion 6. Surface discontinuities a. Root and crown concavity b. Excess penetration c. Excessive and irregular crown d. Misalignment (hi-lo) e. Undercut f. Backing rings	to the weld cross sections. 3. Explain the source of the density variations. 4. Display sample weld sections. 5. Show the sample film and explain. 6. Repeat the procedure for each of the other defects.
B. Viewing Screens	1. A high intensity film viewing screen is desirable for film interpretation. 2. A rheostat-type light intensifier is also a desirable feature. 3. Viewing screen should be free of artifacts. 4. Varying light intensity is an aid in studying shapes of defects.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Ask the group to sketch each of the weld defects discussed in the presentation and show the density profile for each type of defect. Allow one or more students to present each type.

B. Display the sample film on a viewer one at a time to the group. Have individual students identify each defect and its origin. Repeat until each student can identify every defect.

C. Display the film one at a time to the class for identification. Ask the group to identify each film on a sheet of paper to be handed to the instructor. Examine the papers. Review the cause of the defect, the density profile, and the film of each defect which the student fails to identify.

IV. TEST (final check on students' comprehension of material presented)
Test the group on weld defect interpretation by displaying sample films to the group. Ask the students to identify each of the defects by placing their answers on a piece of paper to be turned in for scoring.

V. SUMMARY

A. To become skillful in weld defect interpretation the student should be able to identify weld defects by name.

B. The location of a defect in the weld is often a clue to its identification.

C. Weld defects are also called discontinuities.

D. Some defects are more serious than others so they should be correctly identified by their proper name.

The Next Lesson is: Radiograph Film Interpretation (Castings)

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit	9
Lesson	11
Time	2 hours

Note to the Instructor: This is a practice lesson, time should be provided each week for practice on this material.

SUBJECT: Radiography Film Interpretation (Castings)

AIM (or purpose): To teach the student the fundamentals of casting inspection, the appearance of casting defects on film, and the interpretation of serviceability of castings

TEACHING AIDS: Film viewer
Industrial Radiographic Standards for Steel Castings, ASTM E-71, American Society for Testing Materials, Philadelphia, Pa.

MATERIALS: Sample castings
Sample film

REFERENCES: Defects and Failures in Pressure Vessels and Piping, Helmut Thielsch, 1965, Reihold Publishing Corp, New York, N. Y.

I. PREPARATION (of the learner)

Stress that this lesson should help an individual to recognize casting defects as the images appear on an x-ray film and should help the student to distinguish one type of defect from another. It should also develop an understanding of the cause of many casting defects recognizing that castings often exhibit certain defects which are peculiar to the process. Film interpretation of castings can be explained theoretically; however, there is no substitute for practical experience. In this effort the student will have an opportunity to constantly compare the film and theory in practice interpretations.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Casting defects 1. Gas and blow holes 2. Sand spots 3. Inclusions 4. Internal shrinkage 5. Hot tears and cracking 6. Unfused chaplets 7. Internal chills	1. Make a chalkboard sketch of a casting containing gas pockets. 2. Sketch the density profile corresponding to the casting. 3. Explain and discuss the source of the density variations. 4. Display film showing the defect. 5. Display sample casting with the defect. 6. Repeat the procedure for each of the other type defects.
B. Viewing Screens	1. A high intensity film viewing screen is desirable for film interpretation. 2. A rheostat-type light intensifier is also a desirable feature. 3. Viewing screen should be free of artifacts. 4. Varying lights intensity is an aid in studying shapes of defects.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Ask individuals from the group to explain the origin of each of the casting defects, sketch a cross section showing the defect, and sketch a density profile for the defective casting.

B. Display the sample film to the group one at a time on a film viewer. Have individual students identify each defect and outline its cause. Repeat until the students can identify each type of defect.

C. Show the film again one at a time on a film viewer. Ask the students to identify and record the type of defect on a piece of paper to be turned in. Review the papers. Analyze the cause, the density profile, and discuss the film of each defect type the students fail to identify properly.

IV. TEST (final check on students' comprehension of material presented)

Test the group on casting defect interpretation by displaying sample radiographs on a viewer. Ask the students to identify each defect by placing their answers on a piece of paper. Have students exchange test papers. Review each radiograph on the screen and interpret. Check results.

V. SUMMARY

A. Casting defect interpretation requires practice.

B. Sample reference radiographs are used for practice.

C. Variable light intensity viewing screens are also a valuable training aid.

The Next Lesson is: How to Interpret Lines on Drawings or Blue Prints.

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 10
Lesson 1
Time 1.5 hours

SUBJECT: How to Interpret Lines on Drawing or Blue Prints

AIM (or purpose): To outline and explain the basic lines in drawings or blueprints

TEACHING AID: Chart showing lines with brief explanation identifying each type of line; chart with drawings fully dimensioned. Drawings or blueprints as used in radiography

MATERIALS: 8 1/2" x 11" paper, pencils, and straightedge

I. PREPARATION (of the learner)

Point out that to do an effective job of reading one must be able to interpret type, symbols, lines and the like, even in the simple task of reading a road map. We interpret symbols, lines and a variety of characters.

In drawing and blueprint reading, it is also necessary to recognize and understand the various lines used to construct, measure, and show the design of a machine part or structure. This interpretation of lines and figures is known as blueprint reading and if the task is to be handled effectively, considerable emphasis should be placed on the accuracy of the operations.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Object line	Pass out sample blueprints or drawings as used in radiographic work. Illustrate on chalkboard and point out on actual blueprints or drawings and explain. 1. Is a heavy solid line 2. Represents the real object on a drawing or blueprint

	3. May be shown from several views or angles 4. Ask questions
B. Extension line	1. Is a light solid line 2. Extends from object to indicate points of measurement 3. Seldom touches object (1/16" from object point of measure) 4. Ask questions
C. Dimension line	1. Is a light broken line 2. Is broken for indicated dimensions between points of measurement 3. Has arrow on either end 4. Arrows touch extension lines, usually 1/4" distance from end away from object 5. Ask questions
D. Hidden line	1. Is a heavy dashed line 2. Represents hidden shapes of the object that are obstructed by the exposed view 3. Ask questions

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III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Have students do the following on chalkboard or paper. Give close supervision:

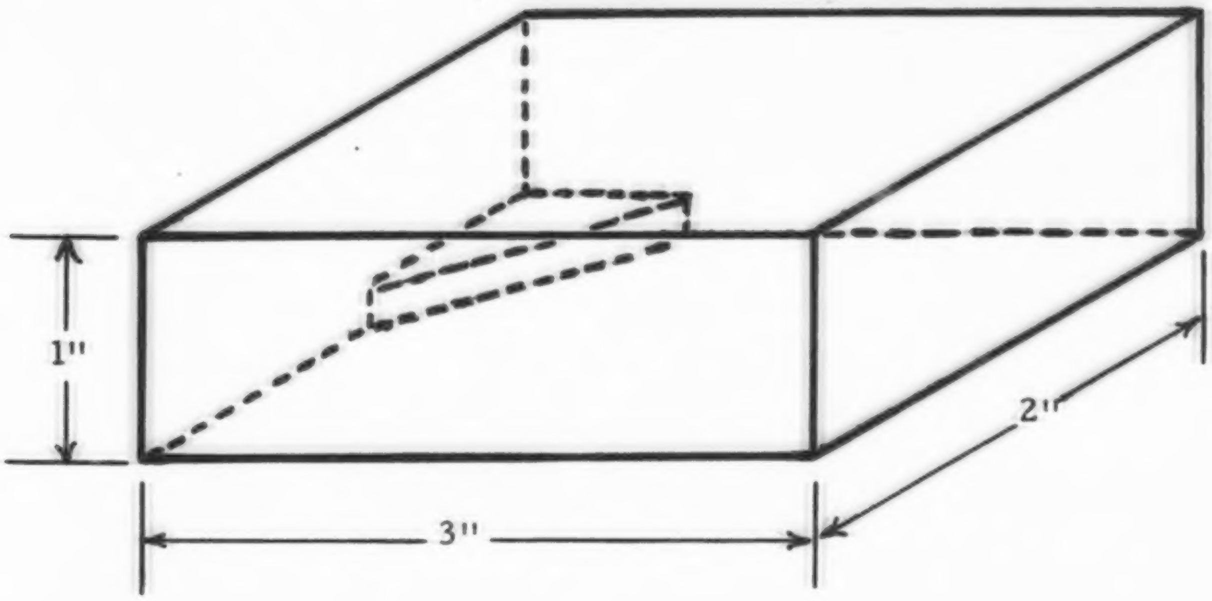
A. Draw or sketch an object 3" long, 2" wide, and 1" thick

B. Add extension lines

C. Install dimension lines, showing dimensions

D. Show a step cut across the back corner of the object, using a hidden line

E. Ask students to locate on drawings or bleuprints the following lines:
   1. Object lines
   2. Extension lines
   3. Dimension lines
   4. Hidden lines



IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What is the line that represents the real object on the drawing?

B. What is a hidden line? Why is it used?

C. What is the difference between a dimension line and an extension line?

Check and discuss.

V. SUMMARY

A. Object line - heavy solid line. Represents the real object on a drawing.

B. Extension line - thin, broken line with dimensions indicated in break. Indicates points of measurements.

D. Hidden line - heavy dash line. Indicates hidden shapes.

The Next Lesson is: Shop Drawings and Blueprints

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit	10
Lesson	2
Time	2 hours

SUBJECT: Shop Drawings and Blueprints

AIM (or purpose): To develop an understanding of the process of blue print production and to assist the student in the interpretation of blue prints

TEACHING AIDS: Film: Shop Drawings, 22 mins., 16 mm, sound, Pennsylvania State University, University Park, Pa.

EQUIPMENT: Film projector and screen

I. PREPARATION (of the learner)

A. Introduce film, giving title and pointing out the following points should be observed or noted while viewing the film:

1. The types of lines used to denote various parts and areas of the image.
2. The number and placement of views necessary to clearly define the part.
3. Methods used to reduce the size of the drawing and the placement of dimensions.
4. The methods of indicating internal sections.

B. Stress that this lesson should help the individual to locate component parts on a drawing that are to be radiographed and should help the radiographer to make sketches indicating where radiographs are to be made or were made on a piece of equipment such as a refinery pressure vessel.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
"Shop Drawings"	Show the film

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Discuss the film, emphasizing the following points in the discussion:
   1. Types of lines used in drawings and what they denote.
      a. Solid lines
      b. Dashed lines
      c. Center lines for axis of rotation
      d. Diagonal lines indicating sectioning
   2. The number of views necessary to define a part.
      a. The plain view
      b. The side view
      c. The front view
      d. Internal details
   3. Methods of scaling
      a. Shortening of uniform sections
      b. Section rotations

B. Have members of the group prepare sketches on chalkboard or paper using the various lines, views and details shown in the film.

C. Reshow the film in the event that any lack of understanding develops.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What type of lines are used for:
   1. Outlining the part?
   2. To show a center of rotation?
   3. To indicate a section?

B. How many views should be shown of a part?

C. Should all details be shown in every view? Why?

D. What is meant by scale?

V. SUMMARY

A. Radiographer sometimes works from a shop drawing.

B. It is important that you be able to identify the location of radiographed parts from a drawing.

C. Sketches sometimes contain several different views of an object.

D. Sketches are not always drawn to scale.

E. Sketches and symbols should indicate what part of weld is to be radiographed.

The Next Lesson is: Graphic Inspection Symbols

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 10
Lesson 3
Time 2 hours

SUBJECT: Graphic Inspection Symbols

AIM (or purpose): To teach the student the standard symbols used on drawings to indicate the place and type of inspection to be employed

TEACHING AIDS: Information Sheet #24 (test)

REFERENCES: Information Sheet #23
Nondestructive Testing Symbols, Military Standard 23A, August 1952, U. S. Department of Defense, Washington, D. C.

I. PREPARATION (of the learner)

This lesson is a continuation of the language of drawing symbols. The symbols discussed in this lesson are particularly useful to the inspectors. With a satisfactory blueprint or shop print the inspector can use these symbols to outline his inspection task without the necessity of further instructions.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The basic symbols	Pass out Information Sheet #23 1. List the basic methods and their symbols on the chalkboard; i.e., RT, MT, PT, and UT. 2. Explain the meaning of the symbols and answer questions.
B. Elements of the testing symbol: 1. Reference line and arrow	1. Draw the reference line on the chalkboard and add the arrow. 2. Explain the purpose of the arrow and the meaning of arrow and opposite side.

	3. Point out that the arrow can point in any direction from either end of the reference line. 4. Invite questions.
2. Test-all-around symbols	1. Add the symbol to the sketch. 2. Explain its meaning.
3. Extent of test	1. Sketch arrow to indicate a test from both sides - Explain. 2. Add information to sketch to indicate the length of the part to be inspected. 3. Add information to show the number to tests required for random testing.
4. Direction of radiation	1. Sketch a symbol indicating the location and distance of the radiation source from the area to be tested. 2. Explain, and discuss.
5. Combination of symbols	1. Sketch a combination welding and testing symbol. 2. Illustrate and explain the method of combining test symbols.
6. Specification	1. Add the tail to the reference line - Explain. 2. Show placement of specification information in the tail of the arrow. Explain and discuss. Invite questions.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Ask several members of the class to draw on the chalkboard symbols to indicate types of tests indicated below:
   1. The symbol for a magnetic particle test of a pipe weld in accordance with ASTM specifications.
   2. A symbol for radiographic inspection of a weld on a plate. The film-focal distance should be indicated at 24" at an inclination of 15 degrees from the perpendicular.
   3. A symbol for a combination ultrasonic test of a plate from the top side and a magnetic particle test from the back side.
   4. A symbol combining the welding of a fillet weld in the field with a magnetic particle inspection in accordance with ASTM specifications.

5. A symbol for the panoramic X-ray of a large diameter pipe weld in accordance with Mil-Std-271.

B. Solicit the assistance of the entire class in checking the symbols drawn for accuracy and defining the meaning of each.

IV. TEST (final check on students' comprehension of material presented)

A. Ask the group to draw the following symbols on a paper to be turned in for checking:
   1. A symbol for radiographic inspection of a butt weld with a film-focal distance of 12" and an inclination of the source from the perpendicular of 30 degrees.
   2. A symbol for a radiographic inspection of a pipe weld in accordance with ASME specifications.
   3. A symbol for magnetic particle and ultrasonic inspection of a weld.
   4. A symbol for magnetic particle inspection of 20" of a power shaft which is six feet long.

B. Pass out the symbol test sheet #24 and ask the group to answer the following questions, to be turned in for checking:
   1. How many different types of tests are indicated on the test sheet?
   2. How many tests are required on the inside of the pipe?
   3. What type of tests are made on the inside of the pipe?
   4. How many welds are to be radiographed in whole or part.
   5. What is the extent of testing required on the welds of this assembly?
   6. Where in the system are the welds located that require two types of tests?

The Next Lesson is: Graphic Welding Symbols

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit	10
Lesson	4
Time	2 hours

SUBJECT: Graphic Welding Symbols

AIM (or purpose): To acquaint the student with an accurate and quick method of determining the welding procedures used in fabrication and to improve an individual's ability to read blueprints

TEACHING AIDS: Information Sheet #26 (test)

REFERENCES: Standard Welding Symbols, AWS 2.0, American Welding Society, New York, N. Y.
Information Sheet #25

I. PREPARATION (of the learner)

Explain that a detailed drawing of each weld in an assembly might be pleasing to the eye; however, few draftsmen can achieve the artistic detail of a professional artist. To convey the necessary information to the craftsmen who must perform the work, engineers and draftsmen have created a language of symbols which adequately tell the workman what is to be done. A knowledge of the welding symbols will aid the radiographer in establishing proper work procedures and help a great deal in the interpretation of processed radiographic film.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Welding symbols	1. Distribute information sheet #25 depicting standard arc welding symbols. 2. Explain the need for symbols as follows: a. Language understood by all b. Easy to learn and draw c. A lot of information in a small space 3. Invite discussion

	4. Explain the use of these symbols in blueprint preparation.
B. The elements of the welding symbol	
1. The reference line and arrow	1. Draw a reference line on the chalkboard and add an arrow. 2. Explain the purpose of the arrow and the meaning of arrow side and opposite side; indicates the side to weld. 3. The arrow can point in any direction from either end of the line. 4. Ask questions.
2. Field weld and weld-around symbol	1. Add the field weld symbol to the sketch. 2. Add the weld-all-around symbol. 3. Explain their meaning. 4. Point out the meaning of the symbol without these elements.
3. Basic weld symbol	1. Add a basic weld or groove symbol to the chalkboard sketch. 2. Explain the meaning of the symbol placement. 3. Show alternate placements.
4. Contour symbols	1. Add symbol to chalkboard sketch. 2. Explain the symbols meaning. 3. Show placement and meaning.
C. Supplementary information	1. Using the information sheet #25 show the various other symbols for the finish, length of weld, groove angle, specification compliance, and root opening. 2. Give other illustrations on chalkboard as needed. 3. Illustrate the placement of information to indicate the length and size of welds. 4. Ask and invite questions.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Suggest one or more students portray on the chalkboard symbols to indicate the following types of welds and accessory information. Have group discuss each:

A. An intermittent chain fillet weld to be completed in the field with a pitch of 5 inches on 2 inch increments.

B. A double "V" groove field weld on a large pressure vessel shell.

C. An example of a shop weld on flat plate with a "U" groove which requires a single pass back weld.

D. The pressure containing field type weld used on piping with a single "V" groove.

E. A field fillet weld of a large slip-on flange welded inside and out. (Provide a sketch or a print of the slip-on flange)

IV. TEST (final check on students' comprehension of material presented)

Pass out test sheet #26 showing different types of welds. Ask tne students to:

A. Identify each type of weld profile shown on the drawing.

B. Indicate the number of shop welds and the number of field welds.

C. Enumerate the number of fillet welds.

D. Indicate the number of groove welds.

E. On a separate sheet of paper, have the students draw the symbol for
   1. A "V" groove field weld for pressure piping.
   2. The field fillet weld on a "T" joint with a fillet leg length of 1/2".

V. SUMMARY

A. Welding symbols condense welding information.

B. Shop welds can be identified and separated from field welds.

C. Knowledge of welding symbols is helpful in writing inspection specifications.

D. Knowledge of welding symbols is helpful in cost estimating of radiographic inspection services.

E. Welding symbols include identification of types of joint preparations required, as well as the length, type and contour of weld.

The Next Lesson is: Testing for Contamination

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 11
Lesson 1
Time 2 hours

SUBJECT: Testing for Contamination

AIM (or purpose): To outline the correct methods and procedures used to test for leakage of radioactive source capsules.

TEACHING AIDS: Empty source capsules
Dummy wipe test kits

REFERENCES: Information Sheet #27

I. PREPARATION (of the learner)

A. Explain to students that early methods of encapsulation proved inadequate and as a result many contamination incidents occurred.

B. Point out the possible hazards of handling source equipment that is leaking and explain why this is vital information for the radiographer.

C. Discuss the need for frequent leak testing of sources and generally indicate the grave hazards that develop if careless or contemptuous attitudes are formed regarding contamination.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The wipe test	1. Explain the purpose of the wipe test and why it is so called. 2. Point out that it is to detect and measure radiation contamination. 3. Show the students a typical wipe test kit and explain the services available to the radiographer. Showing how an area being checked is wiped with a damp swab or towel.

	4. Outline the requirements for authorization to perform wipe tests and the equipment necessary to achieve successful testing. 5. Explain the methods employed to wipe remote controlled equipment and hand cameras. 6. Define the Curie, explaining that it emits 37 billion disintegrations or counts per second. 7. Illustrate on the chalkboard the conversion of counts per second (disintergrations/sec) to curies. 8. Pass out Information Sheet #27.
B. Counting instruments	State the legal capabilities required of the instruments used for counting-ability to measure 0.005 microcuries of ionizing radiation.
C. Leaking sources and contamination	1. Outline the procedures for disposing of leaking sources and explain that a leaking source should be reported immediately by wire or telephone. 2. State the requirements for reporting a leaking source to the regulatory agencies. a. Place source and container in plastic bag to prevent spread of contamination. b. Place bag in locked permanent storage room. c. Notify AEC or State authorities. d. Monitor area for possible contamination. e. Check self with monitoring device and remove contamination as quickly as possible by using shower. NOTE: PLUG SHOWER DRAIN AND HAVE WATER CHECKED FOR CONTAMINATION.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Ask students to explain the purpose of the wipe test and the procedure for obtaining the sample.

B. Have the students calculate the leakage in curies of material from a given number of counts on a counting instrument.

C. Ask students to define the legal requirements for testing and handling of sources which show leakage.

D. Show the students samples of capsules used in industrial radiography and ask for discussion on how leakage occurs.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What is the maximum limit of contamination allowed on a wipe test of a radiographic source?

B. How often are wipe tests required by regulations?

C. What is the procedure when a source is found to be leaking?

D. How many microcuries of leakage has been detected by a wipe test if the counter indicates 50 disintegrations/sec?

E. Where is the wipe made on the testing of remote controlled equipment? On testing hand cameras? On testing loose capsules?

V. SUMMARY

A. Inadequate methods of encapsulation led to wipe testing regulations.

B. Improved techniques still inadequate in the event of an accident while transporting radioactive materials.

C. A. E. C. or State regulatory body arranges for disposal of contaminated materials.

The Next Lesson is: Make a Wipe Test

INSTRUCTOR'S LESSON PLAN
Manipulative Skills

Unit 11
Lesson 2
Time 2 hours

JOB (or operation): Make a Wipe Test

AIM (or purpose): To develop skill in the use of the wipe test kit for contamination testing

TOOLS AND EQUIPMENT: Remote control gamma ray exposure device
Geiger-Muller and ion chamber type survey meters
Beta calibrating source

MATERIALS: Dummy wipe test kits (expendable)
Shipping labels

REFERENCES: Manufacturer's illustrated instructions for use of wipe test kits

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I. PREPARATION (of the learner)

A. Explain the importance of the proper performance of the wipe test, since improper testing could result in the use of leaking or damaged sources and the contamination of the radiographer.

B. Remind students that ionizing radiation cannot be detected by man's senses and that contamination can be caused by very small amounts of radioactive material that cannot even be seen without the aid of a magnifying glass.

C. Explain that long half life gamma emitters are extremely hazardous in the form of contamination.

D. Compare this type of contamination with the effects of fallout from a nuclear detonation but explain that fallout would not be as concentrated.

II. PRESENTATION (of the skills)

Operations or Steps	Key Points (things to remember to do or say)
A. Explain regulations governing wipe tests	Note: Use all precautionary measures and plan demonstration so that it can be carried out according to regulations. Give close supervision. 1. Wipe test required every six months. 2. Special laboratory equipment necessary to check for level of contamination. Explain. 3. Only excessive amounts of contamination can be detected with survey meter. If this occurs isolate contaminated materials in locked storage room and notify AEC or State regulatory body. 4. Background count must be considered in measuring amount of contamination.
B. Demonstrate: 1. Position camera on the floor	1. Place the remote controlled camera on the floor. 2. Extend the control cables to full length. 3. Crank the camera into the full shielded position with the plug inserted and the camera in the locked position. 4. Survey the camera with a meter to make sure the source is in a fully shielded position. 5. Remove the plug from the extension tube port. 6. Caution: The survey meter should be used during the entire wipe test procedure.
2. Use the wipe test kit	1. Remove the wipe test swab from the vial. 2. Insert the swab into the extension tube port.

	3. Swab the port with a circular motion in order to cover the inside surface for a distance of about one-half inch. 4. Return the swab to the vial and replace the lid tightly. 5. Return the plug to the extension tube port and lock the source in place. 6. Tape the lid on the vial to prevent accidental opening. Vial made of plastic. 7. Check the vial with a survey meter to detect possible gross leakage. 8. Caution: Use a separate wipe test kit for each source or surface to be tested.
3. Preparation of tag for mailing, or shipping	1. Write the date, source number, source type and capsule model number on the tag. 2. Tape the tag or label to the vial. 3. Package the vial for shipment using sufficient insulation to prevent breakage.

III. APPLICATION (practice by learner under close supervision)

A. Divide the students into pairs and have each pair perform the entire wipe test, using all precautionary measures and plan demonstration so that it can be carried out according to regulations. Give close supervision.

B. After each individual team completes wipe test have other students offer constructive criticism.

C. If a Geiger counter is available have students test vial containing swab with this instrument after first having checked the background count in the room.

D. Arrange to hide a beta calibrating source under a paper towel near the vial containing the wipe test swab. Have student check the swab with Geiger counter and observe his reactions when counter picks up a reading from the hidden beta button. Be sure tube window is open to allow beta radiation to be detected.

E. If an Ion chamber is the only type of detection instrument available have one member of a team change the zero setting on instrument with the rheostat adjusting knob. This will give a false indication on the rate meter. Ask the other member of the team what he proposes to do since there is an apparent indication of contamination above the allowable level.

F. If training-type gamma sources are available (such as the cobalt 60, five millicurie sources used in Civil Defense classes) the instructor can bring one source into the work area, unobserved by the team performing the wipe test. This will give a high background count and will simulate a contamination problem.

Note: Use all available precautionary measures and plan student demonstration so that it can be carried out according to regulations. Give close supervision.

IV. TEST (performance of skill to acceptable standards)

A. Have each individual student perform a wipe test using the Gamma exposure device and wipe test kits.

B. Have each individual student fill out labels as required.

C. Give students simulated test results and have them record on proper report form.

D. Discuss results.

V. SUMMARY

A. AEC regulations require that wipe tests be performed every six months, or whenever contamination problem is suspected.

B. Contamination cannot be detected without the use of detection instruments.

C. Survey meters cannot be used to determine if contamination is being held at a permissable level. Low level counting instruments must be used.

D. AEC regulations outline reporting and emergency procedures in event contamination is found.

The Next Lesson is: Factors Governing Exposure

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 12
Lesson 1
Time 1.5 hours

SUBJECT: Factors Governing Exposure

AIM (or purpose): To teach the essential factors which govern the time calculation

TEACHING AIDS: Equivalence Factors P. 18 Eastman Kodak Testbook (table)

REFERENCES: Radiography in Modern Industry, 1958, Eastman Kodak Co., Rochester, N. Y.

I. PREPARATION (of the learner)

Explain the importance of this lesson by discussing and emphasizing the following points:

A. The calculation of exposure is the task in which the radiographer has the most difficulty. Explain why.

B. A basic understanding of the methods of exposure calculation is necessary for the student to become a successful radiographer. Give reasons why this is true.

Note to Instructor: This lesson is an overview of all the factors governing exposure. Individual factors will be covered by other lesson plans. The student should not be expected to retain all the information presented at this time.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Factors governing exposure	1. Explain the effect of each factor which alters the exposure setup:
1. Radiation source and strength	a. Source penetrating ability determines its density and thickness applications.
2. Film type	
3. Source to film distance	

4. Type of material being inspected 5. Intensification screens 6. Desired film density 7. Darkroom processing	Source strength is an exposure time factor. b. Film type is an exposure time factor. c. Source to film distance affects image sharpness and is an exposure time factor. d. Type of material being inspected governs type of source used for exposure or KV setting on x-ray exposure. e. Lead intensification screens affect exposure time. f. Radiographic quality. g. Desired film density is governed by adjusting exposure time. h. Darkroom processing time can adjust for improper exposure time.
B. The exposure factor, a proportionality constant	1. Express the relationship between the exposure factor and other parameters of the gamma exposure; i. e. $T=\frac{EFxD^2}{S}$ EF represents film speed, specimen density and thickness and wave length of radiation source being used. D represents source to film distance squared. S represents source strength in millicuries. T represents exposure time in minutes. 2. Explain how the equation can be used to determine the time of an exposure.
C. Exposure charts	1. Explain the origin of exposure factor charts. 2. Outline the methods used for preparation of exposure charts for x-ray generators. 3. Explain why an exposure factor is not a constant for x-ray exposure because KV can be adjusted.

D. Exposure factor corrections	1. Explain the radiographic equivalence factor. Refer to P. 18 Eastman Textbook. Specimen relative densities must be considered when using exposure factor charts. Equivalence factor tables uses aluminum as reference up to 100 KV and steel from 150 KV up. 2. Explain the film factors.
E. Conversion factors for exposure. a. Time-distance corrections b. Time-density corrections c. MaS-distance corrections	1. State the relationship between time and distance; i. e., $\frac{T_1}{T_2} = \frac{D_1^2}{D_2^2}$ 2. Show sample calculations of the above formula. 3. Display the characteristic curve and explain what is shown by the curve. 4. State the relationship between MaS and distance; i. e., $\frac{MaS_1}{MaS_2} = \frac{D_1^2}{D_2^2}$ 5. Show sample calculations of the above formula.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Use the following for discussion:

A. As the students name them list on the chalkboard the factors which govern the radiographic exposure.

B. Have students define the gamma ray exposure factor.

C. Ask students to explain the exposure chart for gamma ray exposure factors and x-ray exposure.

D. Review with the class participating in the discussion the use of correction factors of radiographic equivalence and film factors.

E. Ask students to state the purpose of a characteristic curve.

F. Using a gamma exposure factor chart, have students calculate the time for a typical radiographic exposure.

IV. TEST (final check on students' comprehension of material presented)

A. Suggested questions for a short written test:
1. List five factors which will alter the radiographic exposure.
2. What is a gamma exposure factor?
3. What is meant by radiographic equivalence?
4. What is the purpose of the characteristic curve?
5. What is meant by film factors?

B. With the class assisting check the answers to the test making sure that all answers are corrected.

V. SUMMARY

A. Many factors govern the selection of proper exposure time. (Check off list in A of Step II)

B. Exposure factor is a proportionality constant and differs with each type film and gamma source.

C. Exposure charts simplify exposure computations.

D. Exposure factors are a combination of film speed, KV or MEV rating of radioactive source, and specimen density and thickness.

E. Conversion factors are for time-distance, time-density, and MaS -distance adjustments.

The Next Lesson is: Calculation of a Gamma Exposure

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 12
Lesson 2
Time 2 hours

SUBJECT: Calculations of a Gamma Exposure

AIM (or purpose): To adequately outline the use of mathematical expressions used for exposure calculations

MATERIALS: Film suppliers exposure factor charts for each student, Ansco C70d-31 Table of material or radiographic equivalence factors

REFERENCES: Radiography in Modern Industry, 1958, Eastman Kodak Co., Rochester, N. Y.
Information Sheets #28, #29, and #30

I. PREPARATION (of the learner)

A. It should be pointed out to the student body that radiography is not an exact science, therefore, it will always be important to make use of all information that will help to improve the final product, the radiographer, and hold the element of variability to a minimum. This lesson is calculated to assist the radiographer in correctly calculating the time it will take to make a radiographic exposure of the desired relative density. Inability to calculate exposure time correctly may require that the specimen be re-radiographed one or more times.

B. An explanation should also be given regarding the methods of determining the exposure necessary to produce an acceptable radiograph and how these methods can be applied to various situations.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The exposure factor	1. Define on the chalkboard the exposure factor as a proportionality factor between thickness and time

for a set of standard exposure conditions.

$$EF = \frac{TS}{D^2}$$

where: T=time
S= ource strength
D= ource to film istance

2. Distribute copies of suppliers exposure charts to the students, information sheets #28 and 29.
3. Explain the methods used for constructing an exposure factor chart.
4. Outline the restrictions on an exposure factor chart:
   a. For a single type of film
   b. For definite source type and size
   c. For one type of material
   d. For one set of darkroom conditions

B. Calculation of exposure from exposure factor charts

1. Establish a set of conditions for an exposure. List these conditions on the chalkboard:
   1/2" steel plate, 12" focal distance
   1.5 relative film density, Ansco "A" film, 5 curies Iridium 192.
2. Show the students how to read the chart to obtain the value of the exposure factor.
3. Show typical calculations to obtain the time of exposure using the exposure factor from the chart.
4. Show how to figure the exposure time. The unit cancellation method should be used to avoid the use of the wrong units of measure.

C. Radiographic equivalence factors

1. Issue information sheet #30 and define the radiographic equivalence factor.

	2. Show the procedure for obtaining the equivalent thickness of steel from the thickness of another material. 3. Explain and illustrate by working problem on chalkboard using information listed on exposure chart.
D. Problems	1. Example problems 2. Work problems 3. Ask questions 4. Determine that there is full understanding.
E. Exposure factor tables	1. Tables for frequently used pipe and plate sizes are time savers. 2. A separate exposure factor column is necessary for each type film. 3. Outside pipe diameters do not vary with pipe wall thickness. 4. Use of tables cut down figuring time. 5. Work sample problems on chalkboard using information sheet. 6. Ask questions.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Request students to illustrate to the class on the chalkboard, the calculation of exposure time using a different set of conditions for each student.

B. Have various individuals determine the time for an exposure using a set of conditions listed on the chalkboard. Student should restate these conditions on their individual papers.

C. Suggest that students calculate exposure times for the following problems using an exposure table:

a. 1" steel plate 12" in diameter. Use 5 curies, Iridium 192
b. 8" pipe, 3/8" wall thickness. Use 5c. IR. 192

D. Have group calculate exposure time for the following problems using an Ansco exposure chart:

a. 1" steel, focal distance 10", relative density 2.0, using Ansco "A" film and a 1 curie source of Iridium 192.

b. 2" steel, focal distance 14" relative density 1.5 using Ansco "C" film and 10 curies of Iridium 192.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What is the time for exposure of a 1" thick steel plate at a film-focal distance of 24" for a density of 2.0 using Ansco A film and a 20 curie source of Iridium 192?

B. What is the time for exposure of a 4" thick aluminum plate at a film-focal distance of 36" for a density of 2.0 using Ansco B film and a 15 curie source of Iridium 192?

C. If a piece of Ansco A film was exposed through 1" of steel for 2 minutes from a distance of 24" to produce a density of 2.0, what is the strength of the Iridium 192 source needed to make the exposure?

Check and discuss.

V. SUMMARY

A. Exposure factor represents the kind of gamma material and type of film being used.

B. Charts and tables enable you to figure exposure times quickly and accurately.

C. Exposure time considerations include:
  1. Specimen material
  2. Film-focal distance
  3. Relative density of film
  4. Film type
  5. Type of gamma source
  6. Source strength

The Next Lesson is: Conversion Formulas and Graphs used in X-ray Exposure Calculations

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 12
Lesson 3
Time 2 hours

SUBJECT: Conversion Formulas and Graphs used in X-ray Exposure Calculations

AIM (or purpose): To clarify and provide practice in the use of the mathematical expressions employed in exposure calculations

REFERENCES: Radiography in Modern Industry, 1958, Eastman Kodak Co., Rochester, N. Y., Pages 42 and 43.

I. PREPARATION (of the learner)

A. Outline the topic and explain the purpose of this lesson. Pointing out that although it is possible to make radiographs without making use of the characteristic curves for each type film, an understanding of the curves will eliminate a lot of guesswork in selecting the most appropriate film for a given assignment. These curves are especially helpful in selecting the right film when radiographing castings having a wide latitude of thickness. Operators who guess at the proper type of film to use are sometimes referred to as "picture takers" implying that their capabilities are limited to opening and closing a shutter. Therefore, take advantage of these characteristic curves and eliminate the possibility of being so categorized.

B. Stress the fact that a student must know the correct method of determining the x-ray exposure times necessary to produce satisfactory or acceptable results if he is to succeed as a radiographer.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Conversion formulas	1. Explain that a conversion formula is used to adjust exposure time for focal-film distance, film speed, and Ma settings.

2. Stress the need for conversion formulas when using X-ray exposure charts.
3. Outline the necessity for having an accurate exposure chart before application of the formulas pointing out that if the exposure chart is inaccurate, results after applying conversion formulas will also be inaccurate.

B. Time-distance relation

$$\frac{T_1}{T_2} = \frac{D_1^2}{D_2^2}$$

1. Show the relationship between the inverse square law and this relationship. The exposure time (T) required for a given exposure is directly proportional to the square of the focal-film distance (D).

$$\frac{I_1}{I_2} = \frac{D_2^2}{D_1^2}$$

2. Demonstrate on the chalkboard by showing a sample calculation for a change in the focal distance.

C. The Ma - time relation

1. Define the reciprocity law MT=C (Constant) showing that an increase in ma results in a proportinate decrease in exposure time.
2. Outline the limitations of the law. Refer to Table V page 38 of the Eastman Textbook.
3. Show sample chalkboard calculation for a change in the time of exposure and the change in milliamperage required.

D. The density- time relation

1. Have students turn to page 43 of the Eastman Textbook.
2. Review the information presented by the curves.
3. Review the definition of logarithms and antilogarithms.

4. Explain the determination of exposure increase required to double the density of Type AA film if the original density is 1.5.
5. Show sample calculations to alter the density from any value to another.

E. Problems

1. If a satisfactory radiographic exposure was made in 4 minutes at 1 foot what would be the exposure time at 9 inches (.75').
2. An exposure made in 5 minutes at 4 ma would take how long to make at 6 ma?
3. A 1.5 Density was obtained in 2 minutes with Kodak AA Film. What would be the time for a 2.0 density.
4. Solve problems with students participating.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Ask for an explanation of the purpose of the ime- istance relationship, and solve a sample problem on the chalkboard.

B. Request that someone define the reciprocity law, explain the limits of accuracy, and solve a sample problem on the chalkboard.

C. Have another member of the group explain to the class the method of determining the exposure change from one density value to another using the same exposure working the problem on the chalkboard as it develops.

D. Suggest that all participants work a sample problem using:
   1. The time-distance relationship
   2. The reciprocity law
   3. A characteristic curve to calculate a change in exposure time.

E. Additional problems to be used for drill.

1. If a radiograph was made in 4 minutes @ a 3 foot focal distance, how long would it take to make the same radiograph @ 2 feet?

2. If an X-ray picture was made in 2 minutes with 150 kv and 4 ma how long would it take to make same exposure @ 1.5 ma?

3. A radiograph was made with AA film, 1. 5 density, in 2 minutes, how long would it take to make same radiograph if 2. 5 density was required?

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. If satisfactory exposure is obtained in 2 minutes at a distance of 24", what is the time required at 36"?

B. If an acceptable exposure is obtained in 3 minutes at 5 ma, how long will the exposure be if the current is raised to 15 ma?

C. If a radiograph was made from an exposure chart to obtain a density of 1. 0 using Kodak AA film, how much should the exposure time be increased to obtain a density of 2. 5?

Check and discuss

V. SUMMARY

A. Conversion formulas and graphs help to make calculations of variations in film-focal distance, film density, ma settings and film speed.

B. Time and distance variations require use of the inverse square law.

C. Law of reciprocity is used in adjusting for ma settings.

D. Film density changes are calculated by a logarithmic method.

E. Practice problems are considered helpful in reviewing these calculations.

The Next Lesson is: How to Use X-ray Exposure Charts

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 12
Lesson 4
Time 2 hours

SUBJECT: How to Use X-ray Exposure Charts

AIM (or purpose): To promote the use of x-ray exposure charts

REFERENCES: Radiography in Modern Industry, 1958, Eastman Kodak Co., Rochester, N. Y. (Charts on pgs. 40 through 46)

I. PREPARATION (of the learner)

A. Develop interest by pointing out that x-rays and gamma rays are sometimes considered alike in every aspect except that their origins differ. Discuss the possibility that exposure time can be figured by one common method for x-rays and gamma rays explaining to the class what the basic difference is, and its effect on time calculations.

B. Point out that this lesson will explain the various methods that can be used to figure x-ray exposure times. X-ray quality can be altered by adjusting a knob on the x-ray console controlling the kv (kilovoltage). This means that with the x-rays you can select the radiation quality that should give the best results for a particular application. This also means that exposure time will differ with each setting. An x-ray exposure chart is a graph showing the relation between material thickness, kilovoltage, and exposure. Although exposure charts are available from manufacturers of x-ray equipment, corrections must be made for different brand generators. It is, therefore, considered desirable to prepare an exposure chart for ones own x-ray generator.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The x-ray exposure chart	1. Refer students to pages 40 to 46 in the reference textbook explaining the purpose of the exposure chart.

	a. Exposure chart usually offers a choice of about four KV selections. b. Exposure time is usually shown in milliampere seconds. c. One or two film-focal distances are usually listed. d. One relative film density is used. e. Conversion factors are available for changes in speed and film density.
B. Figuring exposure from the x-ray exposure chart	1. Establish a set of conditions for an exposure listing these conditions on the chalkboard. 2. Determine the kilovoltage for the exposure from the graphs of recommended voltage. 3. Illustrate the selection of the correct exposure from the chart. 4. If the exposure is given in milliampminutes, show how to obtain the time in minutes. If one ma is being used, read time directly; if two ma are used divide by 2, etc.
C. Film factors for change of film types	1. Define film speed and film factor. Film speed is relative; coarse grain film is faster than fine grain film. If one film has a relative speed of 1 and another film has a relative speed of 2, then the exposure factor for film with relative speed of 2 is twice as long as that for film with a relative speed of 1. NOTE: An industrial x-ray film is seldom described as being coarse grained, it is usually described "less fine", "very fast". 2. Explain how this factor can be used to obtain an equivalent exposure with a different type of film. Use film speed comparison between the two type films and increase or decrease time accordingly.

D. Film speed tables

1. Turn to page 55 of Eastman Textbook. Refer to the column on relative speed. Discuss differencies in film speed between Kodak AA and Kodak M film. (Ratio is 30:200 at 200 KV). Discuss how ratio changes with KV change.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Suggest that students calculate the exposure for several sets of conditions. Ask the students to explain their method of figuring to the other students.

B. Have others in the group establish the time for exposure using a set of conditions listed on the chalkboard. Students should also list these conditions as a part of the solution to the problem.

C. Invite participating members to determine the new exposure time caused by changing the film from that specified on the exposure chart to another type.

IV. TEST (final check on students' comprehension of material presented)
NOTE: Written Test

A. In radiographing a part made of 3/4" thick steel, what is the exposure time to obtain a radiograph of 1.5 density on Kodak AA film using a film-focal distance of 40" using 200 kv and 2 ma?

B. What is the exposure time of the same set up if the film is Kodak M?

C. If the part is steel 1 1/4" thick, what is the exposure time to obtain a radiograph of 1.5 density on Kodak M film using a film-focal distance of 40" and 3 ma?

V. SUMMARY

A. X-ray exposure charts are used to figure x-ray exposure times.

B. Resultant time can be given in milliampere minutes, or milliampere seconds.

C. Each line on the chart represents a different kilovoltage setting.

D. Times are shown for a 1 milliamperage setting. Settings higher than 1 will reduce exposure time proportionally.

The Next Lesson is: X-ray Exposure Charts

EXPERIMENT SHEET
X-ray Exposure Charts

Unit	12
Lesson	5
Time	4 hours

SUBJECT:

Construction of an exposure chart for an industrial x-ray generator

NOTE:

Instructor performs all operations

INTRODUCTORY INFORMATION:

Problems of exposure calculation have been presented in the class room using an x-ray exposure chart. These charts are published and are generally furnished by the manufacturer; however, it is generally considered good practice to prepare a chart on each generator because of their variations in output. It is the purpose of this experiment to develop an x-ray exposure chart for a particular generator.

MATERIALS AND EQUIPMENT:

X-ray generator and exposure facilities
Film cassettes loaded with Kodak AA film and .005" lead screens front and back
Steel step wedges, 1/4" to 1 1/2" in 1/4" steps
Densitometer
Lead sheet for masking wedges
Darkroom facilities
Semi-log graph paper, two cycle, 70 divisions
Clean rags

REFERENCES:

Radiography in Modern Industry, 1958, Eastman Kodak Co., Rochester, N. Y., page 40

PROCEDURES:

A. Clean and examine cassettes before loading film. Use lead screens which have no visible defects.

B. Single load eight cassettes with Kodak AA film.

C. Set up x-ray machine for an exposure using a 36" film-focal distance and maximum milliamperage.

D. Place a film directly under the focal spot of the machine at 36" distance. Center the step wedge directly under the focal spot and mask all sides with lead sheeting. Mark the film for identification.

E. Make an exposure at 140 KV for 1 minute.

F. Repeat steps D and E using 160, 180 and 200 KV.

G. Repeat the procedure of D, E, and F using KV settings of 140, 160, 180, and 200 and a six minute exposure time.

H. Develop all eight film simultaneously at 68°F. for 5 minutes. Fix and dry.

I. Prepare a chart of KV settings versus thickness for a density of 1. 5.

J. Using a transmission densitometer, determine the thickness which produces a density of 1. 5 for the film 1 through 4.

K. The exact thickness will have to be determined by interpolation between the two steps where the density is 1. 5.

L. Record the thickness opposite the KV on the prepared chart.

M. Note the ma-min for this set of values; for example, 5 ma for 1 minute equals 5 ma-min.

N. Repeat the procedure for the film set 5 through 8.

O. Record the thickness versus the KV which produced a density of 1. 5.

P. Note the ma-time for this set of values; i. e. , 5 ma for 6 minutes = 30 ma-min.

Q. Prepare a sheet of log paper by marking the thickness across the bottom and the ma-min along the side. The first cycle of the log paper will cover 1 ma-min to 10 ma-min.

R. Plot the points for thickness at a line representing the lower ma-min setting of exposures 1 through 4.

S. Plot the points for the ma-min setting for exposures 5 through 8.

T. Connect the point for each KV setting by straight lines. Extend these lines to the edge of the graph.

U. Label each KV line with the appropriate value.

CAUTION: Make sure only one thickness lead screens are used for this experiment.

CONCLUSIONS:

A. The prepared chart is valid for a density of ____________.

B. Type ___________ must be used when using this chart.

C. If an exposure was made of a 3/4" thick piece of steel using a 36" film-focal distance, 5 ma, and 160 KV, the time of exposure would be __________.

D. The purpose of the lead sheet masks is __________________.

The Next Lesson is: Scattered Radiation

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 12
Lesson 6
Time 2 hours

SUBJECT: Scattered Radiation

AIM (or purpose): To describe and develop proven methods and techniques of reducing scattered radiation thereby improving radiographic quality

TEACHING AIDS: Film samples, sample masks, film cassettes, screens and gamma ray collimators

REFERENCES: Nondestructive Testing Handbook, Volume I, 1963, Society for Nondestructive Testing, Evanston, Illinois
Information Sheet #31

I. PREPARATION (of the learner)

A. Introduce the subject explaining that this lesson will deal with minimizing the adverse effects of scattered radiation through the use of scatter controls.

B. Explain that when performing gamma radiography of welds, castings, and parts, the irradiated area and the hazard to personnel in the area can be materially reduced by using simple scatter control devices.

C. Stress the need for acquiring this knowledge and how important it is in protecting the life of the radiographer.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The effects of scattered radiation on radiographic quality	1. Explain the role of scattered radiation in: a. Reducing contrast b. Increasing film fog c. Reducing sensitivity d. Producing undercut 2. Show film samples

II. PRESENTATION (of the information -- continued)

Instructional Topics	Things to Remember to Do or Say
B. Sources of scattered radiation 1. The specimen 2. Cassettes 3. The floor or exposure surface 4. Filters	Illustrate by chalkboard sketches the creation of scattered radiation from each of the sources listed.
C. Methods of scatter control 1. Masks 2. Filters 3. Diaphragms 4. Collimators 5. Intensification screens	1. Describe the function of the mask and display several examples: Masks are usually thin lead sheets placed around the outside edges of a specimen to absorb scatter. 2. Define masking methods using clays, shot, and liquid lead solutions. 3. Explain the functions of the filter in radiography and how it reduces scatter filtering out soft, scatter producing rays before they reach the specimen and film. 4. Display typical diaphragms and collimators used to contain beam spread. 5. Illustrate by chalkboard sketches the function of each of these scatter control devices.
D. Exposure variations from the use of scatter control devices	1. Explain why the use of masks, filters, and collimators can result in increased exposure time. Show how the total relative film density is the product of primary radiation and scatter. 2. Emphasize the reduction in personnel hazard gained from the use of these devices, and how scatter control devices reduce these hazards by reducing environmental scatter. 3. Pass out information sheet #31 showing examples of exposure time with collimation variations.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Invite students to describe to the class the origin of scattered radiation and its effect on the quality of the radiograph.

B. Ask members of the group to outline several sources of scattered radiation and the methods of controlling the scatter.

C. Suggest that students draw a chalkboard sketch of a radiographic setup using good scatter control techniques on a part of complicated shape.

D. Have the group define the increased safety derived from the use of scatter control devices.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What are the advantages that ensue from the reduction of scattered radiation?

B. Why does the reduction in scatter generally result in increased exposure time?

C. List three scatter control devices and tell how they reduce scatter.

D. Describe at least three methods of masking to reduce scatter.

E. What function does the collimator serve besides the reduction of scatter?

Check and discuss.

V. SUMMARY

A. Radiation scatter has a very detrimental effect on image quality.

B. Many factors contribute to creation of this adverse effect.

C. Several methods are used to minimize this adverse effect.

D. Elimination of scatter effect increases exposure time but also increases image quality.

E. Personnel safety is increased by controlling environmental scatter.

The Next Lesson is: The Control of Scattered Radiation

EXPERIMENT SHEET
The Control of Scattered Radiation

Unit	12
Lesson	7
Time	3 hours

SUBJECT:

Methods of reducing scattered radiation and improving radiographic quality

NOTE:

Instructor performs all operations

INTRODUCTORY INFORMATION:

Production of high quality radiographs requires the use of many techniques. The use of good exposure techniques, proper selection of film, and good dark room procedures will not always guarantee a satisfactory radiograph. Reduction of scattered radiation is also an essential necessity for the detection of very fine defects. This experiment will show the difference in quality obtained from good scatter control techniques.

MATERIALS AND EQUIPMENT:

X-ray generator and exposure facilities
Film cassettes, 0.005 and 0.010 lead screens, and film
2" thick aluminum casting
Lead sheet, barium clay, and lead acetate solutions
Penetrameters
Film viewer
Lead numbers
Dark room facilities with equipment, timer, materials, etc.

PROCEDURE:

A. Single load a film cassette with film and remove the intensifying screens.

B. Set up the x-ray generator for an exposure of the aluminum casting using 160 KV and the exposure chart constructed in a previous experiment. Use radiographic equivalence factors to determine the thickness of steel to be used in the exposure determination.

C. Place a 1" thick piece of wood on a steel plate and position the film on the wood block directly under the focal spot of the x-ray generator. Center the casting on the film. Mark the film for identification. Place a 2-2T penetrameter on the casting in the area of interest.

D. Expose the film to obtain a density of 2.0 in the area of interest.

E. Single load another cassette with the same film using a .005 front and a 0.010 back screen.

F. Place the film on a thick sheet of lead under the focal spot of the generator.

G. Position the part on the film using a good masking technique. A water tight aluminum pan is required if liquid masking is used. CAUTION: Liquid lead solutions are poisonous and must be handled with care.

H. Mark the film for identification and place a 2-2T penetrameter on the casting.

I. Place a diaphragm on the tube port of the x-ray generator.

J. Expose the film using the same exposure as in the first film.

K. Develop both films simultaneously at 68°F. for 5 minutes. Fix and dry.

L. Place film on a viewer and compare the results.

CONCLUSIONS:

A. The increased sensitivity of film number two is due to ___________.

B. The effect of the screens in the cassettes is to _______________.

C. The two film ___________ or __________ of the same density in the area of interest.

D. The purpose of the lead back up sheet in exposure number two was to ______________________.

The Next Lesson is: Exposure Changes for Changing Densities

EXPERIMENT SHEET
Exposure Changes for Changing Density

Unit	**12**
Lesson	**8**
Time	**3 hours**

SUBJECT:

Changing the density of radiographs from one value to a second desired value

NOTE:

Instructor performs all operations

INTRODUCTORY INFORMATION:

The exposure charts for x-ray radiography are constructed for a fixed density. It is often necessary to change the density of a radiograph to comply with specifications, increase contrast, or to improve the readability of the film. The radiographer should be able to adjust the density of the film by adjustment of the exposure time given by the exposure chart.

MATERIALS AND EQUIPMENT:

X-ray generator and exposure facilities
Film cassettes and Kodak AA film
Sample part for inspection
Densitometer
Characteristic curves for type AA film
Darkroom facilities including equipment, materials, lead numbers, etc.
Logarithm tables

PROCEDURE:

A. Single load film cassettes with type AA film.

B. Set up the x-ray generator for an exposure of the sample part using the exposure chart constructed in a previous experiment.

C. Place a film directly under the focal spot of the machine and center the sample part on the film. Mark the film for identification.

D. Make an exposure in accordance with the exposure chart.

E. Using the characteristic curve calculate the increase in exposure time necessary to increase the density of the film to 2.5 in the area of interest.

F. Change the time setting on the x-ray machine.

G. Place a second film under the machine and center the part on the film exactly as in the first exposure. Mark the film for identification.

H. Expose the second film in accordance with the new time setting.

I. Develop both films simultaneously at 68°F. for five minutes. Fix and dry.

J. Using the densitometer determine the density of each film at the point of interest on the image.

K. Measure the density at the lowest and highest densities on each film .

L. Record the values on the lab work sheet.

CONCLUSIONS:

A. The effect on contrast from the increase in density is ____________.

B. The density ______________ increase the same for all thicknesses of the part.

C. The increase in time necessary to achieve a density of 3.5 in the area of interest is ________________.

D. The same amount of time _______________ or ___________ ____________ be required to raise the density at the lowest density spot to 3.5 as was required for the original area of interest because ___________________.

The Next Lesson is: Changing Focal Distance

EXPERIMENT SHEET
Changing Focal Distance

Unit 12
Lesson 9
Time 3 hours

SUBJECT:

Obtaining equivalent exposures when changing the focal distance.

NOTE: Instructor performs all operations

INTRODUCTORY INFORMATION:

The exposure charts for x-ray radiography are constructed using a fixed film-focal distance. It is often necessary to alter this distance because of the geometry of the part, obstructions in the radiation beam path, or a desire to increase sensitivity and resolution. The radiographer should be able to make the simple calculations required to achieve an exposure equivalent to that obtained at the standard focal distance.

MATERIALS AND EQUIPMENT:

X-ray generator and exposure facilities
Film cassettes and film
Sample part for inspection
Densitometer
Dark room facilities, supplies and materials
Lead numbers
Six foot tape

PROCEDURE:

A. Single load film cassettes with film selected for the experiment.

B. Setup x-ray generator for an exposure of the part selected using the exposure chart constructed in a previous experiment.

C. Place the film directly under the focal spot of the machine and center the sample part on the film. Mark the film for identification.

D. Make the exposure in accordance with the exposure chart.

E. Move the tube head of the machine from 36" to 24" focal distance.

F. Place a second film under the machine and center the part on the film exactly as on the first exposure. Mark the film for identification.

G. Calculate the change in time required by moving the tube head to the new position.

H. Expose the new set up in accordance with the calculated time.

I. Develop both film simultaneously at 68°F. for 5 minutes. Fix and dry.

J. Using the densitometer, determine the density of each film at the same point on the image of the part.

K. Record the values on the lab work sheet.

CONCLUSIONS:

A. If the procedures are correctly followed, the density of the film will be ____________________.

B. When the film-focal distance is shortened, the intensity of the radiation beam is ____________________.

C. When film-focal distance is shortened, the sharpness of the film is ____________________.

D. If the procedure did not produce the desired results, the difficulty could be caused by incorrectly ______________ the distance or an error in ________________.

The Next Lesson is: Standards for Protection Against Radiation

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 13
Lesson 1
Time 2 hours

SUBJECT: Standards for Protection Against Radiation

AIM (or purpose): To outline the regulations imposed by the controlling agencies who issue licenses for use and possession of radiation producing devices

REFERENCES: Information Sheet #3, #32, #33 and #34
Copy of Title 10, Federal Register, Part 20, "Standards for Protection Against Radiation"

I. PREPARATION (of the learner)

A. Introduce the topic and develop student interest by touching briefly on the radiation banking concept and the minimum age of a radiographer. Explain what the maximum accumulated dosage is that a person may receive before he can no longer work as a radiographer, and how long a radiographer must be idle from work before he may return to his duties after receiving the maximum allowable dosage.

B. Point out how this lesson will help the individual to better understand the safety rules and regulations that govern the handling, use, transfer, disposal, and possession of radioactive materials.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Definitions under Part 20	1. Refer to Information Sheet #3 and read the pertinent part of each definition to the class.
1. 20.3-Byproduct material Calendar quarter Licensed material Occupational dose Radiation Radioactive material Restricted area Unrestricted area	2. After reading each definition translate the legal terminology into terms readily understood by the students.

II. PRESENTATION (continued)

Instructional Topics	Things to Remember to Do or Say
2. 20.202 - Personnel monitoring equipment Radiation area High radiation area	
B. Permissible dose and radiation levels 1. 20.101 - Exposure of individuals	1. Read and explain all pertinent regulations to the student. 2. Explain the exceptions to the general rule. 3. Perform sample chalkboard calculations to determine maximum dosages for individuals.
2. 20.102 - Determination of accumulated dose	1. Read the regulations pertaining to records and calculation of dosages. 2. Display Form AEC-4 to the students. 3. Explain the preparation of the form.
3. 20.104 - Exposure of minors	Read and explain the regulation to the students.
4. 20.105 - Permissible levels of radiation in unrestricted areas	Read and explain all pertinent matters to the students.
C. Precautionery procedures 1. 20.201 - Surveys 20.202 - Personnel monitoring	1. Refer to Information Sheets # 32 and 33. 2. Read and explain the regulations to the students.
2. 20.203 - Caution signs and labels	1. Refer to Information Sheet #34. 2. Display the sample signs and explain where each is required by regulations.
3. 20.206 - Posting of notices	Display AEC-3 forms and explain the requirements for posting them.
D. Waste disposal 1. 20.301 - General requirements	1. Read the section pertaining thereto and explain to the students. 2. Explain why the exceptions are not generally applicable to radiographic sources.

E. Notifications
  1. 20.403 - Incidents
  2. 20.404 - Former employees
  3. 20.405 - Report of over-exposure

Read each section and explain to the students.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Have individual students explain to the class the regulations for:

A. Rules for exposure of individuals
B. Determination of accumulated dosage
C. Exposure of minors
D. Permissible levels of radiations in unrestricted areas
E. Requirements for use of monitoring devices, signs, and notices.
F. Disposing of radioactive materials
G. Notifying the control agency of incidents and accidents

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What is the normal whole body dosage allowed per calender quarter for individuals working in a restricted area?

B. If a radiographer were 25 years old, what would be the maximum accumulated dose he could have from occupational exposure?

C. What are the limits of radiation intensity marked by the "Radiation Area" and the "High Radiation Area"?

D. When are surveys required by regulations?

E. How are unwanted radiographic sources usually disposed of?

F. Where is the "Notice to Employees" sign required to be posted?

G. What are the exposure levels which require immediate and 24 hour notification that an accident has occurred?

H. What is the basis of the requirements for reporting over-exposure which do not exceed the levels specified for incidents or accidents?

I. Who is responsible for furnishing information on an employee's previous exposure history? How is this information obtained? Who requests the information?

Check and discuss

V. SUMMARY

A. A thorough understanding of the AEC standards for protection from radiation are necessary in order to qualify for an AEC Radiography License.

B. Permissible dose and radiation levels must be observed and current records of dose levels must be maintained.

C. All precautionary procedures must be enforced.

D. Waste disposal procedures seldom apply to radiography licensees.

E. Notification time limits and procedures must be understood and maintained.

The Next Lesson is: Licensing of Byproduct Materials

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 13
Lesson 2
Time 1.5 hours

SUBJECT: Licensing of Byproduct Materials

AIM (or purpose): To develop an appreciation and understanding of the requirements and provisions for obtaining a license to use byproduct materials

REFERENCES: Information Sheet #3

I. PREPARATION (of the learner)

A. Develop an interest in the subject by discussing the purpose of the license.

B. Explain that federal laws control the possession, handling and use of synthetic radioactive materials and that the U. S. Atomic Energy Commission regulates the possession, use and handling of these materials. So-called "Agreement States" control these operations in their respective areas and some of these have reciprocal agreements among themselves. In the spring of 1966 there were about twelve agreement states in the United States.

C. Discuss the fact that while some radioactive materials can be obtained in very small amounts, usually ten microcuries or less, without a license, this small amount would have little or no value in radiography.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Definition in Part 30 1. Agreement states 2. Byproduct materials 3. Radiographer 4. Radiographers assistant 5. Sealed sources	1. Refer to Information Sheet #3 and read the definition of each term from the regulations. 2. Define each term in language understandable to the student. 3. Ask for questions and discuss all aspects 4. Give examples

B. Exemptions 1. AEC contracts 2. Carriers 3. Weak concentrations 4. Luminous dials	1. Read the pertinent part of each applicable section and explain to the students. 2. Ask for questions and discuss. 3. Give examples
C. Licenses 1. Types - General and Specific 2. Applications 3. Requirements for issuance 4. Terms: a. Transferral b. Limits of use c. Implied and written 5. Expiration, termination and renewal	1. Read the applicable sections on each of the listed topics. 2. Explain the regulations to the students. 3. Ask for questions 4. Give examples
D. Enforcement 1. Modification and revocation 2. Recall 3. Violations	1. Read the pertinent part of each section and explain all subject matter to the student. 2. Ask questions 3. Cite practical examples

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III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Have individual students explain to the class the regulations for:

A. Persons who are exempt from licensing for use and handling of radioactive materials.

B. The types of licenses available and to whom they apply.

C. The terms of issuance, usage, and the transferral of licenses.

D. The legal measures available to the government for enforcement of the provision of a license.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What are the two types of licenses issued for use of byproduct materials? What is the difference?

B. Who is exempt from license requirements?

C. What is the difference between a radiographer and a radiographer's assistant as defined by the regulations?

D. What is an agreement state? What authority does an agreement state have over licensing?

E. What type of penalities can be imposed on persons who violate the terms of a license?

Check results and discuss.

V. SUMMARY

A. The Atomic Energy Commission regulates the safe handling, use and possession of synthetic radioactive isotopes.

B. The licensee must have a thorough understanding of these regulations.

C. These regulations include use, handling and possession of gamma sources used in radiography.

D. Regulations also cover: enforcement of rules, types of licenses, requirements for issuance of licenses, definitions, agreement states and exemptions.

The Next Lesson is: Licenses for Radiography

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 13
Lesson 3
Time 2 hours

NOTE TO INSTRUCTOR: Repetition or application of this lesson should be given as often as possible

SUBJECT: Licenses for Radiography

AIM (or purpose): To explain and clarify the governmental requirements for licensed radiographic operations

REFERENCES: Information Sheet #3

I. PREPARATION (of the learner)

A. Point out that this lesson will help the individual to know the licensing requirements for possession, use, and the handling of radioactive materials. The AEC must control the use of this material in order to protect the operator and the public from the hazards of radiation. The lesson includes definitions, licensing requirements for radiographers, safety requirements and precautionary procedures.

B. Stress the importance of acquiring the information contained in this lesson because:
1. The regulations contain the minimum training requirements for an individual acting as a radiographer in a licensed operation.
2. The regulations contain the minimum safety program required by a licensee for the protection of his employees.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Definitions under Part 34 1. Radiography 2. Radiographic exposure device 3. Storage container	Read the definitions to the student and explain them having a short discussion as to the how, why, when, where and what.

B. Licensing requirements for radiography 1. Training program 2. Written procedure manual 3. Internal inspection program 4. Organizational structure for operational control	1. Read the entire section on requirements and explain and discuss. 2. Display an operational procedure manual. 3. Read Appendix A outlining the minimum training program.
C. Safety requirements 1. Radiation levels from exposure devices 2. Locks on exposure devices. 3. Storage areas 4. Survey meters 5. Wipe testing 6. Inventories 7. Emergency procedures 8. Personnel monitoring devices	1. Read and explain the applicable sections of the regulations and discuss them. 2. Read the applicable sections of the procedure manual dealing with these topics and discuss them thoroughly. 3. Explain the purpose of the procedure manual, explaining all aspects of the manual.
D. Precautionary procedures 1. Survellience of radiation areas 2. Posting of signs 3. Survey of radiation areas	Read, explain and discuss the applicable sections of the regulations, inviting all questions as they develop.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Have various students explain:

A. The minimum requirements necessary to obtain a license for radiographic operations

B. The maximum radiation intensity allowed to be emitted by a locked exposure device

C. Requirements for locking of storage and exposure devices

D. The basic requirements for survey meters

E. The need for wipe testing

F. The necessity of logging of source usage

G. The procedure for conducting inventories.

H. The number and type of personnel monitoring devices required by law

I. The requirements for posting of notices.

J. The essential need for conducting radiation intensity surveys during radiographic operations

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IV. TEST (final check on students' comprehension of material presented)
NOTE: Written Test

A. How often must survey meters be calibrated?

B. How frequently should wipe tests be performed?

C. When must an inventory be made of exposure devices and sources?

D. What are the requirements for tagging of sources and marking of storage areas?

E. When are exposure devices allowed to be unlocked?

F. What personnel monitoring devices must be worn by all radiographers?

G. What is the purpose of the operating procedure manual?

H. When must physical radiation surveys be performed?

I. What is the operating range of a survey meter which conforms to governmental regulations?

Check and discuss.

V. SUMMARY

A. Certain definitions must be studied and remembered if regulations are to be understood.

B. Licensing requirements include formal training, written procedures for company operation, and organizational control structures.

C. Many specific safety regulations must be observed.

D. Precautionary procedures must be spelled out.

The Next Lesson is: Emergency Procedures for Radiographic Operations

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit	13
Lesson	4
Time	2 hours

SUBJECT: Emergency Procedures for Radiographic Operations

AIM (or purpose): To stress the need for adhering to safe practice when emergencies occur in radiographic operations

REFERENCES: Copy of typical operating and administrative procedures

I. PREPARATION (of the learner)

A. Introduce the subject and develop interest by pointing out that a radiographer must be capable of coping with emergencies which may arise while operating or transporting exposure devices. He may also be required to handle other emergencies caused by fires in the area where the exposure device is stored, or is being used, and in cases of suspected theft of radioactive materials.

B. The lesson will cover a variety of subjects and will help the individual to understand the importance of a licensee's emergency and operating procedures. Point out that these written procedures must be approved by the AEC.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Accidents involving radioactive exposure devices	1. Explain that accidents can occur regardless of the amount of care exercised. 2. Cite examples of accidents: i.e., fire in the exposure area, objects falling on the equipment, and auto accidents while transporting materials.
B. Problems involving malfunction or breakage of exposure devices	1. Outline the procedures for posting signs, barricading, and alerting proper officials. 2. Warn against attempts to repair

	or recover devices when the radiographer is without experience in these functional areas. 3. Inform the students of agencies and individuals who should be contacted for assistance. 4. Caution against leaving the area unattended.
C. Problems involving stolen equipment	Instruct the students in the correct procedures for notifying the local regulatory officials of the theft.
D. Problems involving fire	1. Explain the importance of returning the source to the locked position in case of fire or a fire alarm. 2. Instruct in the removal of equipment from the hazard area. 3. Explain the notification procedures necessary if sources are exposed in the fire area. 4. Outline the assistance which must be rendered to fire fighters when sources are in the fire area.
E. Problems involving vehicle accidents	1. Instruct the student in the importance of removing injured personnel as a first action. 2. Explain why the area should be immediately surveyed and made secure. 3. Explain the importance of informing law enforcement officers of any hazards. 4. Impress on the student the necessity of keeping curiousity seekers from the area and notifying the proper officials of the accident.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Ask the students to explain:

A. The procedures to follow in case of a malfunction or damage to an exposure device.

B. The proper action to take when equipment is stolen, explaining why.

C. What to do in case of fire and the reasons for the action.

D. How to handle a vehicle accident in which radioactive materials are involved.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What persons and officials are to be notified if equipment is stolen?

B. If a fire breaks out in the area in which a radiographer is working, what is the first action to be taken?

C. What is the first concern of a radiographer involved in a vehicle accident where people are injured and equipment is damaged?

D. Who can a radiographer always turn to for assistance if he cannot contact his designated safety officer?

E. Under the circumstances should a radiographer leave a source which has been damaged?

Check and discuss.

V. SUMMARY

A. Accidents involving radioactive materials continue to happen despite the strict exacting regulations that cover it uses and handling.

B. Many accidents occur because of negligence, apathy and contempt on the part of the user of radioactive materials.

C. Stolen equipment must be reported to the AEC or the State immediately so that the danger created by the incident can be minimized by warning the public of the potential hazard that exists.

D. Emergency operating procedures must cover the measures to be taken in case of fire involving radioactive materials.

E. Emergencies involving transportation of radioactive materials must also be covered in the Emergency Operating Procedures.

The Next Lesson is: Record Keeping for Radiographic Operations

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 14
Lesson 1
Time 2 hours

SUBJECT: Record Keeping for Radiographic Operations

AIM (or purpose): To outline the type records and reports required for radiographic operations

REFERENCES: Information Sheets #3, #35, #36, #37, #38, and #39

I. PREPARATION (of the learner)

A. Center a short discussion around record keeping that students know, i.e., (income tax, bank book, employment, etc.) stressing the need for record keeping.

B. Point out that failure to keep adequate records is a legal violation of the license to possess radioactive materials and that failure to maintain record files can result in a citation for non-compliance with the regulations and result in possible revocation of a license.

C. Explain the importance of this lesson and stress that it will help the individual to set up and keep current the records that are required of the licensee and that the AEC requires that certain records pertaining to radiation safety be kept.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Why records are maintained	1. Explain the legal requirements for record keeping in that a federal law requires it and that AEC inspectors check these records for discrepencies. 2. Explain the advantages of adequate records to counteract and discourage employees claims of malpractice. 3. Impress on the student that the prime objective of record keeping is to insure his own safety.

B. Daily record requirements 1. Daily dosimeter records 2. Ultilization logs 3. Job survey records 4. Set-up sketches	1. Distribute sample report forms. 2. Explain the proper methods for completing each form. 3. Explain why each is required and the extent of detail required. 4. Fill out each sample form while discussing procedures. 5. Invite questions.
C. Periodic records 1. Film badge summary and records 2. Dosimeter summary 3. Quarterly inventory 4. Wipe/leak tests 5. Survey meter calibration 6. Unscheduled surveys 7. Container and exposure device surveys	1. Distribute sample report forms. 2. Explain the source of information and the proper methods of completing the forms. 3. Illustrate techniques for summation of exposure records. 4. Explain the nature and purpose of an unscheduled survey.
D. Historical records 1. AEC-4 2. AEC-5 3. Transfer and disposal records	1. Distribute sample forms. 2. Show chalkboard calculations to determine allowable dosage. 3. Explain the need for maintaining transfer and disposal records; AEC keeps a careful awareness of each and every source of nuclear radiation under their control.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Have individual students explain:
  1. The daily records required.
  2. The records required on a periodic basis and the time interval of each.
  3. The historical records of employees and equipment.

B. Invite students to fill in practice forms supplying all necessary information.

C. Create a variety of pseudo situations to fully cover the lesson in all its aspects, giving each student the opportunity for practice and questions.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What records require preparation on a daily basis ?

B. What is the time interval for survey meter calibration? Wipe Test? Source inventory?

C. What record is necessary before a prospective radiographer may work for a new employer ?

D. How often are dosimeter readings entered in the records ?

E. What is the value of the sketch prepared of the exposure area ?

Check and discuss.

V. SUMMARY

A. A well kept, current set of records is necessary if you are to keep your AEC radiography license.

B. Some records require daily entrys.

C. Proper entry on each form is essential.

D. Records are inspected periodically by AEC representatives.

E. Legitimate records are most helpful in planning safety improvements.

The Next Lesson is: Permanent Exposure Facilities

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 15
Lesson 1
Time 3 hours

SUBJECT: Permanent Exposure Facilities

AIM (or purpose): To cover in detail the features and construction characteristics of radiation exposure facilities

REFERENCES: Radiography in Modern Industry, 1958, Eastman Kodak Co., Rochester, N. Y.
Radiation Safety in Industrial Radiography with Radioisotopes, AECU 2967, 1954, U. S. Atomic Energy Commission
Information Sheet #40

I. PREPARATION (of the learner)

Explain that the construction of exposure rooms is a very expensive endeavor and that many rooms have been constructed which later proved inadequate or inconvenient because of poor planning. A familiarization with desirable features is mandatory if mistakes are to be avoided. Emphasize that every radiographer should be able to make some constructive contribution to the design of a facility for exposure.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Construction materials	1. Outline the use of lead and concrete for x-ray and gamma ray radiation shielding. Wide lead sheet for floor cover and wall cover is desirable but quite fragile and expensive. 2. State the maximum energy levels for practical use of each type shielding. 3. Compare construction costs for the various types of construction. 4. Draw chalkboard sketches of methods of lead construction

	such as lapping and nail head covering. Refer to page 114 of the Eastman textbook.
B. Construction features	1. Draw a chalkboard sketch of a typical exposure room layout or refer to Information Sheet #40. 2. Explain the desirability of keeping metallic members of construction to a minimum thereby minimizing scatter. 3. Describe how vacant areas or idle work space can be used for shielding; Employing the distance factor. 4. Define the limits of allowable intensity at the outside boundary of the exposure room 2mr/hr. 5. Describe the construction of pits and vaults for the storage of isotopes. 6. Describe the use of circuit breakers and entry way interlocks; Line voltage to X-ray tube should be interrupted when the door is opened while the unit is in operation.
C. Openings	1. List the requirements for openings in the exposure room walls or floors; i.e., control cables, piping, ventilation, access doors, etc; Should be angled. Refer to page 114, of the Eastman textbook. 2. Describe the construction methods of shielding around openings. See Information Sheet #40. 3. Draw a chalkboard sketch of a shielding maze at a major entry way. (Labyrinth)
D. Monitoring devices	1. Describe the console type instruments for continuous radiation monitoring. Automatic monitor alarms are activated when 2 mr/hr.

is exceeded.

2. Explain why the survey meter must be used in addition to the automatic devices. Survey meters are portable and do not rely on line voltage for power. A survey meter is carried into the exposure room.
3. Describe warning light systems. Red light when radiation field exists. Green light when radiation field does not exist.

E. Auxiliary equipment

1. Explain the need for utilities, water lights, power, and air conditioning.
2. Explain the need for hoists, cranes, and exposure tables. To speed up production less lifting and positioning of specimen and equipment.
3. Explain the desirability of keeping metallic materials out of the exposure room to eliminate scatter.
4. Elaborate on the use of collimators for gamma radiography to reduce scatter.

III. **APPLICATION** (drill, illustrations, analogies, oral questions or assignments)

A. Have several students draw a sketch of an exposure room for use with 20 curies of Cobalt 60 and 50 curies of Iridium 192. Show calculations for determining the thickness of the walls. Justify the use of construction materials.

B. Have other students;
1. Add safety devices to the design.
2. Describe auxiliary equipment needed.
3. Indicate control devices needed for the design.

C. Invite questions and promote discussion.

IV. **TEST** (final check on students' comprehension of material presented)
NOTE: Written Test

A. What type of material would be most economical for exposure room construction if a 300 KV X-ray generator were the only source of radiation? If Cobalt 60 is to be employed?

B. What techniques are used to shield openings in exposure room walls?

C. What type of safety devices are employed in construction of exposure facilities to insure against accidental entry?

D. Why is metal construction material (other than lead) undesirable in the exposure room?
Check and discuss.

V. SUMMARY

A. Permanent exposure facilities are very desirable in radiographic operations.

B. Selection of proper materials for exposure room will improve the quality of radiographs by minimizing the effects of scatter radiation.

C. Automatic interlock systems on all entrances to exposure room are very desirable.

D. Radiation monitoring devices are necessary for this type of installation.

The Next Lesson is: X-ray Tubes

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 16
Lesson 1
Time 2 hours

SUBJECT: X-ray Tubes

AIM (or purpose): To illustrate and describe the characteristics of commercial x-ray tubes

TEACHING AIDS: Defective x-ray tube to be used for demonstration

REFERENCES: Nondestructive Testing Handbook, Volume I, Section 14, 1963, Society for Nondestructive Testing, Evanston, Illinois

I. PREPARATION (of the learner)

A. Write aim of lesson on the chalkboard and point out that this lesson explains the characteristics of various types of x-ray tubes and the uses of each type. Although some radiographers may not have an opportunity to advise on new equipment purchases, they will find this information useful for a variety of other purposes.

B. Identify the many different types of commercial x-ray generations and describe their individual identifying features. Use this opportunity to develop interest by relating some of the advantages and disadvantages of each type.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Tube components	1. Draw a chalkboard sketch of a typical hot cathode vacuum x-ray tube.
1. The anode	
2. The cathode	
3. The target	2. Explain the function and construction of each component, describing the materials used.
4. The envelope	
5. The filament	
6. The window	3. Label the parts of the tube as previously listed in tube component.
	4. Display sample tube.

B. X-ray tube targets
   1. Target materials
   2. Inclined targets
   3. 360 degree emission
   4. Rotating anodes
   5. Reduced focal spot tubes

1. Define the optimum characteristics of target materials:
   a. High melting point
   b. High atomic number
   c. High termal conductivity
   d. Low vapor pressure
2. Draw chalkboard sketches of the various geometric shapes of targets.
3. Explain the advantages of each type of target design:
   a. 360° emission target for circumferential shots.
   b. Rotating target for longer target life
4. Explain the advantages of the smaller focal spot in that it reduces geometric unsharpness.
5. Define and explain "heel effect".

C. Efficienty and heat dissipation

1. Define the efficiency of the x-ray tube for low and medium voltages explaining that as the voltage is lowered the penetrating ability of the x-ray is also lowered.
2. Explain the reason for the lack of efficiency (x-rays result in less than 1% of energy created in tube)
3. Explain techniques for dissipation of heat from the anode:
   a. Tungsten target surrounded by copper heat dissipator
   b. Oil and water circulated around the anode
   c. Metal heat dissipating fins
4. Define the duty cycle outlining the percentage of the total working day that an x-ray generator can be operated without overheating.

D. Special construction features
   1. Focusing cuts
   2. Hooded anodes

1. Draw chalkboard sketches of each of the special features.
2. Explain the advantages of each feature:
   a. Focusing cups collimate the high speed electrons toward tungsten

	target b. Hooded anode improves geometry of the electrodes
E. Beryllium windows	Discuss the advantage of a beryllium window in an x-ray tube, explaining that it provides maximum radiographic contrast for thin or low density materials.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Have each student sketch on paper a typical inclined target hot cathode vacuum x-ray tube.

B. Ask individual students to:
  1. Sketch the x-ray tube on the chalkboard
  2. Explain the function of each part
  3. Discuss the target in detail and sketch other target designs
  4. Sketch and explain the purpose of special features which are used to increase the performance of the tube
  5. Approximate the efficiency of x-ray tubes and tell how heat is dissipated from the anode.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. Draw a sketch of a hot filament, inclined target, high vacuum x-ray tube.

B. Label all of the parts of the tube.

C. Define the function of the filament, the anode, the target, and the envelope.

D. Why is the efficiency of x-ray tubes very low?

E. Outline the advantage of a small focal spot size.

F. What is the purpose of an anode hood and the beryllium window?

Check and discuss.

V. SUMMARY

A. X-ray generators consist of two main components, the control console and the tube head.

B. The tube head contains the x-ray generating tube.

C. X-ray tube focal spot size is important. It should be as small as possible.

D. The duty cycle of the tube is very important and depends upon the tube's ability to dissipate excessive heat generated while in use.

The Next Lesson is: X-ray Generator

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 16
Lesson 2
Time 2 hours

SUBJECT: X-ray Generator

AIM (or purpose): To develop an understanding of the basic circuitry of industrial x-ray generators

TEACHING AIDS: An x-ray generator with top of control panel removed to expose the internal wiring

MATERIALS: Colored pencils

REFERENCES: Nondestructive Testing Handbook, Volume I, Section 14, 1963, Society for Nondestructive Testing, Evanston, Illinois

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I. PREPARATION (of the learner)

Introduce the subject and tell the group that the basic circuitry of x-ray generators will be discussed in detail. Although generators vary slightly in design and placement of meters, fuses, and circuit breakers, all generators are basically the same. As shown in schematic drawings, all circuitry also seems to be of the same general nature. It should be pointed out that knowledge of the basic circuitry is most useful when the radiographer by necessity must repair his own equipment.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The basic circuit 1. Fuses 2. Switch 3. Line voltage compensator 4. Voltmeter 5. Timer 6. Milliammeter	1. Pass out Information Sheet #14. Sketch a typical self-rectified x-ray generator circuit on the chalkboard.

7. Filament transformer 8. X-ray tube	2. Explain the function of each of the components as previously listed under A, the basic circuit. 3. Trace the current flow as it passes through the circuit.
B. Current characteristics 1. Self-rectifying 2. Valve tube half wave rectification 3. Full wave valve rectification	1. Draw chalkboard sketches of the voltage wave form applied to the tube of a self-rectifying tube. 2. Show the effect of self-rectification. 3. Draw a simple bridge circuit and explain how valve rectification is achieved. 4. With chalkboard illustration explain the advantages of the full wave valve rectification.
C. Tank unit designs 1. Grounded cathodes 2. Grounded anodes 3. Center ground systems	1. Define a tank unit and explain how it differs from externally fed high-voltage units. 2. Draw sketches of each of the various tank-type circuits. 3. Explain the advantage of each on the chalkboard.
D. Separated unit machines	1. Sketch the layout of this type machine by block diagrams. 2. Explain the use of rod anodes by illustrating their ability to make exposures in areas too small for conventional equipment. 3. Explain why these units are generally limited to fixed installations (360° radiation pattern creates a hazardous condition outside of the exposure room). 4. Explain the unlimited duty cycle and the ability to use the x-ray generator continuously without the danger of overheating the tube.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Have several students make a chalkboard sketch of a self-rectified x-ray generator.

B. Suggest that others:
   1. Label all components.
   2. Explain the function of each component
   3. Draw a sketch of the applied and the rectified wave form of this generator.
   4. Explain the advantage of full wave rectification

C. Ask other students to describe the various tank unit circuitry designs and explain their advantages to the group.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. Draw a sketch of a self-rectifying x-ray generator circuit.

B. Label all essential parts.

C. Draw arrows to indicate current flow in the circuit.

D. Explain the advantages of the grounded anode and the grounded cathode tank units.

E. What are the advantages of separated unit construction? What are the disadvantages?

V. SUMMARY

A. Self-rectified x-ray circuit is usually employed in a tank-type, or self-contained, portable x-ray unit.

B. Self-rectified x-ray circuits have a relatively low milliamperage output.

C. Rod-anode type units are used where access to exposure area must be made through a relatively small opening.

D. Rod-anode units are capable of making a circumferential exposure.

E. Constant potential circuits are used to increase penetration, reduce exposure time, and produce longer tube life. These units are almost always stationary or fixed.

F. Rectified high-voltage circuits allow a more compact design plus hi tube output.

The Next Lesson is: Set-up, Connecting, Preheating of X-ray Generator and Tube

INSTRUCTOR'S LESSON PLAN
Manipulative Skills

Unit	16
Lesson	3
Time	1 hour

JOB (or operation): Set-up, Connecting, and Preheating of X-ray Generator and Tube

AIM (or purpose): To develop skill in conditioning x-ray tubes before applying high voltages

TOOLS AND EQUIPMENT: X-ray exposure facilities
X-ray generator
X-ray tubes - (new and used)

REFERENCES: Equipment manufacturers instruction manual
Nondestructive Testing Handbook, Volume I, 1963, Society for Nondestructive Testing, Evanston, Illinois

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I. PREPARATION (of the learner)

Point out that this lesson will provide instruction in the correct procedure for operating the x-ray generator, stressing that improper procedures could result in damage to the x-ray tube, which is relatively expensive and not an easy item to install.

Explain that the tube must be warmed up slowly at the beginning of the working day otherwise the radiation output will fluctuate and life of the tube may be materially shortened.

II. PRESENTATION (of the skills)

Operations or Steps	Key Points (things to remember to do or say)
A. Setup x-ray generator	Place generator as if to make exposure. 1. Rotate kv and ma controls to the minimum settings (Manufacturers recommendations).

B. Preset controls	2. Set line voltage control to the proper value 220v or 110 v.
C. Connect cables	1. Connect tube head to control panel. 2. Connect to power line. 3. Caution: Always connect ground lead to proper ground.
D. Turn on power switch	1. Check indicator lights to insure that generator is energized (Lights should be on).
E. Set timer	2. Check kv and ma readings for minimum values (Check manufacturers machine rating) Place timer on maximum value (Check range of generator)
F. Turn on high voltage	1. Press the kv button to energize the high voltage. 2. Caution: Generator is now producing dangerous radiation. Do not stand or walk in front of tube head. Increase kv slowly to one-half of the maximum rated value. Increase ma to one-half the rated maximum value.
G. Increase kilovoltage	1. To warmup generator wait one minute after making initial adjustment. 2. Increase voltage 10 kv every minute until maximum value is obtained.
H. Increase milliamperage	3. Caution: X-ray generators which have been stored for long periods of time should be "seasoned" according to manufacturers recommendations. To season, warm up slower and longer.
I. Increase kv by steps	4. The warmup is performed slowly to prevent tube damage and to give constant radiation output rather than a fluctuating output. 5. Examine sample tubes and explain and discuss parts that are easily damaged.

III. APPLICATION (practice by learner under close supervision)

A. Supervise the students in performing the demonstrated x-ray tube set up and preheat procedure.

B. Have all students discuss and explain why the warmup procedure is essential.

C. Suggest that points of caution be repeated by all to impress the seriousness of the subject.

IV. TEST (performance of skill to acceptable standards)

NOTE: Demonstration

A. Have each student set up the x-ray generator from the beginning. Test for use of proper safety precautions and proper sequence of operations.

B. Rotate the assignment of warming up the x-ray generator each day.

C. Post the warmup sequence on the lid of the x-ray control console.

V. SUMMARY

A. The x-ray tube is the most expensive and one of the most fragile parts of an x-ray generator.

B. Tubes cannot be replaced quickly and efficiently in the field.

C. An x-ray generator's behavior can vary between individual tubes.

D. A properly timed warmup period is essential.

E. Heat dissipation from x-ray tubes is a major problem on field units.

The Next Lesson is: Auxiliary Equipment for Handling X-ray Generators

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 16
Lesson 4
Time 1 hour

SUBJECT: **Auxiliary Equipment for Handling X-ray Generators**

AIM (or purpose): To acquaint students with the various devices employed to position and transport x-ray equipment

TEACHING AIDS: Photos of x-ray equipment and auxiliary handling equipment

REFERENCES: Manufacturers literature
Industrial X-ray Handbook, Allan Lytel, 1962, Howard W. Sams Co. Inc., Indianapolis, Indiana

I. PREPARATION (of the learner)

Develop student interest by relating the fact that when a commercial photographer shoots certain pictures he is required to use necessary or auxiliary equipment to make an effective shot.

The job of a radiographer would be most difficult, in fact, almost impossible, if he were required to use an x-ray generator without the benefit of supporting equipment. Various types of handling devices have been devised to lighten the physical labor of radiography and to increase the production rate of routine jobs. Several of the more common devices will be discussed in this lesson. For example, the matter of moving an x-ray generator through a long section of welded pipe or the positioning of an x-ray tube for overhead exposures.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Tube stands for portable tank units	1. Display photographs of the several types of tube stands or display the actual equipment. 2. Explain and discuss the limits and uses of tube stands.

	3. Display photos of portable cranes and mechanical positioners used with tube-tank units. Discuss importance of these aids and give examples.
B. Positioners for fixed installations	1. Display photos of overhead rails and boom cranes used to position x-ray equipment. Explain their use, giving examples. 2. Show a photo of a production exposure box explaining its importance and purpose. 3. Discuss photos of precision positioning devices used to control beam orientation outlining their use and the assistance they render. 4. Show photos of semi-fixed fork lift and motorized equipment, explaining their advantages.
C. Special purpose devices 1. Pipe line crawlers 2. Vertical tank wall crawlers 3. Pipe girth weld positioners	1. Display photos of these special devices. 2. Explain the operation of these devices. 3. Discuss how the devices are used to speed production or to accomplish difficult jobs.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Have all students outline the procedures for:

A. Positioning a portable x-ray machine to make a radiograph of a 6" pipe 10 feet from the ground in a refinery.

B. Setting up the equipment to make a radiograph of a 36" pipe line girth seam using both internal and external techniques.

C. Making an exposure of a section of a large oil storage tank if the weld is vertical and 15 feet from the ground.

D. Radiographing a rudder tab in place on the airplane.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Oral Quiz

A. How can the expense of fabricating auxiliary equipment be justified?

B. If the radiographer were given a long production run of small parts to be inspected, what type of set up would probably be most economical?

C. What is the advantage of a pipeline crawler over external exposure devices?

V. SUMMARY

A. Tube stands and jigs are available from x-ray equipment manufacturers.

B. Special types of auxiliary equipment such as "crawlers" have been patented and are used extensively in pipeline construction.

C. Vertical wall crawlers and centering devices are used on tanks and pressure vessels.

The Next Lesson is: The X-ray Generator

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 16
Lesson 5
Time 2 hours

SUBJECT: The X-ray Generator

AIM (or purpose): To emphasize the need for exercising the proper care in the use and handling of x-ray generators

TEACHING AIDS: A defective or damaged x-ray tube

REFERENCES: Nondestructive Testing Handbook, Volume I, Section 14, 1963, Society for Nondestructive Testing, Evanston, Illinois

I. PREPARATION (of the learner)

A. Introduce the subject and invite consideration of the matters to be discussed on the basis that the information is both essential and quite interesting.

B. To insure satisfactory performance of x-ray generators, it is necessary to have knowledge of the many factors which can cause a malfunction. Following certain basic and accepted procedures in the care and maintenance of the equipment will insure the radiographer that the x-ray will perform satisfactorily. X-ray generators that remain in a fixed position or location usually require less care and maintenance than the portable field units and frequently have a longer duty cycle in warmer climates because the units can be kept cool by controlling tube head temperature with circulating air, oil or water and by controlling exposure room temperature.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. X-ray tube ratings	1. Explain the meaning of kvp, ma, kvp-ma product, and duty cycle ratings.

   a. Kvp refers to kilovolt potential of an x-ray generator
   b. Ma refers to its milliamperage range
   c. X-ray exposure time is the product of kvp and ma
   d. Duty cycle ratings refer to length of time an x-ray generator can be used without overheating and the length of time it must remain off before being used again. This, of course, varies with the heat-dissipating features of the generator.
2. Explain the function of the thermal cut-off switch and how the thermal cut-off temperature effects the duty cycle.
   a. The thermal cut-off switch shuts off power to the tube head when the temperature in the head reaches a predetermined limit.
   b. Power remains off until tube head temperature returns to normal, but will not automatically turn itself on as this could create a safety hazard.
3. Explain the relation of the thermal control parameters to tube life and how overheating the tube head can shorten tube life.

B. Expected tube life
   1. Design life
   2. Guaranteed life

1. Inform the students that x-ray tubes are expected to produce several thousand hours of satisfactory service if properly handled.
2. Explain the inability of the suppliers to determine abuse and how this determines the guaranteed life.

C. Causes of failure

Explain, discuss and illustrate as necessary.
1. Mechanical failures caused by mechanical shock.
2. Ring fracture of glass caused by

internal stress due to poor annealing of glass.

3. Puncturing of glass caused by faulty mounting and/or bubbles in glass.
4. Filament burn-out due to excessive heating in which case filament evaporates and burns out. Excessive filament voltage can be caused by defective connections.
5. Inverse filament burn out caused by backfiring in tubes fed with alternating current because of over-loaded focal spot.
6. Melted focal spot caused by load, exceeding instantaneous ratings, the effect of poor control being exercised by the user. It can also be caused by timer failure in the ma circuit.
7. Melted anode caused by exceeding heat-storage capacity.
8. Gassy tube, the result of tube overload or a poorly gassed tube.

D. Aids to longer tube life
   1. Preheating
   2. Careful handling

1. Explain why x-ray tubes should be preheated before applying high voltage.
2. Outline the procedure for storage, transportation, and handling of x-ray tubes to minimize shock.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Have individual students define:
   1. KVP
   2. KVP - MA product
   3. Duty cycle
   4. Thermal cut-off temperature

B. Suggest that students outline the various reasons for x-ray failures.

C. Have other students explain to the class the methods normally used to avoid or delay tube failure.

D. Invite all students to discuss the procedures for preheating an x-ray tube before using it for an exposure, being sure to always give the reasons why.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What are three possible consequences of thermal overloading of an x-ray tube?

B. How do x-ray tubes become gassy in service?

C. Why should an x-ray tube be preheated before applying high kv?

D. What is the proper method of preheating an x-ray tube?

E. What is meant by a thermal cutoff temperature?

F. What are the consequences of adjusting the cutoff temperature to gain a higher duty cycle than designed?

G. Approximately how long should a well-cared-for x-ray tube perform satisfactorily?

V. SUMMARY

A. X-ray tube ratings include maximum milliamperage and kilovoltage settings that may be controlled by automatic overload switches.

B. Thermal overload diaphragms and switches are also used.

C. Tube life usually depends upon the manner in which it was used and not upon the total time of use.

D. Careful preheating of the x-ray tube, observance of the suggested duty cycle and careful handling of the unit to prevent shock will prolong the life of the tube and other parts of the equipment.

The Next Lesson is: Measuring X-ray Tube Heel Effects

EXPERIMENT SHEET
Measuring X-ray Tube Heel Effect

Unit 16
Lesson 6
Time 3 hours

SUBJECT:

Measuring the variation in x-ray tube intensity due to the Heel Effect

NOTE:

Instructor performs all operations

INTRODUCTORY INFORMATION:

The beam characteristics of x-ray tubes depend partially upon the angle of inclination of the target with respect to the axis of the cathode. The beam intensity diminishes toward the anode side of the tube and increases toward the cathode side. Knowledge of the characteristics of the machine can be used to advantage as well as prevent the production of inadequate film information.

MATERIALS AND EQUIPMENT:

X-ray generator and exposure facilities
Film cassettes and film
Densitometer
Characteristic curves of the film
Dark room facilities including all materials, lead numbers, etc.

PROCEDURE:

A. Single load two 14" x 17" film cassettes with film which displays a near linear response to exposure from a density of 1.0 to 3.5. (Kodak M or Ansco B)

B. Setup x-ray machine for an exposure.

C. Place the two film cassettes tightly end to end to form a plane 14" x 34".

D. Position the tube head over the film with the focal point exactly 26 3/4" from the film.

E. Using a tube port pointer, align the focal spot directly over the abutting edges of the two film at the center of their 14" edges.

F. Mark the film with suitable identification in order to be able to identify film position with the respective ends of the tube head.

G. Using approximately 150 kv, expose the film for a density of 3.0 (If exposure factors are not known, make several trial exposures on small pieces of film in 5 x 7 cassettes before performing steps 3 through 6).

H. Develop both film simultaneously at 68°F for 5 minutes. Fix and dry.

I. With a crayon or pencil, draw a line 1/4" offset from the center line of the film. Draw the line the full length of the 17" dimension.

J. Commencing at the edge which was directly under the tube port, determine the density every 1/2" until the opposite side has been reached.

K. Prepare a table of distance in degrees for recording the density values.

L. Label the center as "zero" degrees with negative distance toward the anode side and positive distance toward the cathode. (Each 1/2" equal one degree).

M. Opposite the distance on the chart, place the value determined by densitometry.

N. Using the characteristic curves, determine the log of relative exposure for each value of density.

O. Using the log of relative exposure of the center point, divide each of the other values by this value and express as a percentage.

P. Enter this percentage value on the chart opposite the proper distance.

Q. Prepare a plot of emission angle vs. intensity using percentage values from the chart. (See Nondestructive Testing Handbook, pgs. 14/30.) Enter a value for every four degrees.

CONCLUSIONS:

A. For near uniform exposure results, the object should not be more than ____________ inches in diameter if this film-focal distance is employed.

B. For near uniform exposure, the ratio of diameter to focal distance should be ____________ for this machine.

C. The heel effect be used to advantage when __________ __________ distance must be kept to a minimum.

D. If density readings are made across the film plane, changes in density are also noted. The source of this difference is ____________________.

E. The density decreases for all angles above the center line of the focal spots is explained by the _________ __________ law.

F. The ____________ electrode of the tube is nearest to the electrical connection.

The Next Lesson is: Design Characteristics of Gamma Cameras.

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 16
Lesson 7
Time 1.5 hours

SUBJECT: Design Characteristics of Gamma Cameras

AIM (or purpose): To illustrate and stress the various design features of gamma ray exposure devices

TEACHING AIDS: All available gamma camera equipment
Dummy source pigtail

REFERENCES: Nondestructive Testing Handbook, Volume I, Section 26, 1963, Society for Nondestructive Testing, Evanston, Illinois
Title 10, Federal Register, Part 34, Licenses for Radiography and Radiation Safety Requirements for Radiographic Operations
Information Sheets #42 and #43

I. PREPARATION (of the learner)

Write aim of lesson on chalkboard, introducing the topic and explaining that all gamma ray exposure devices are essentially of the same basic design; however, each manufacturer has incorporated individual features which differentiate his equipment from that of his competitors. The individual features of the different cameras may result in increased safety, reduced weight, or ease of operations; or they may act to produce the opposite results and for this reason the radiographer should be familiar with the essential design features of available gamma exposure equipment.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Shielding materials 1. Lead 2. Tungsten 3. Depleted uranium	1. Define shielding equivalent. 2. Draw a chalkboard sketch of density vs. HVL (Half value layers) and indicate points for the various shielding materials. 3. Distribute information sheets #42, and #43.

	4. Illustrate by chalkboard sketch of a camera cross section showing the use of various construction materials.
B. Locking devices 1. Separate containers 2. Locking plugs 3. Pinned shutters 4. Pigtail locks	1. Display available equipment with different locking devices. 2. List and explain other types of locks by use of chalkboard sketches. 3. Display source pigtail and explain how locking mechanisms are designed to prevent removal during cable disconnects.
C. Radiation leakage 1. At camera surface 2. At surface of an outer container	1. Read the applicable section of AEC Title 10, Part 34 concerning limits of radiation levels for exposure defices. 2. Explain the technique used by manufacturers of enclosing the shield in a larger container to meet the requirements of the regulations.
D. Extension and control cables	1. Display webbed metal and plastic source extension tubes. 2. Illustrate by demonstration the ease of damage to some types of tubes. 3. List and explain the intended purpose of odometers and safety lights: a. Safety lights, red and green, indicate whether source is outside or inside the body of the exposure device. b. Odometers indicate distance source capsule has moved away from the stored position inside the body of the exposure device. 4. Explain the dangers of complete reliance on these safety devices. 5. Outline the maintenance procedures for cranks and cables.

a. Prevent kinking of cables and housing
b. Periodically check cable odometer zero setting
c. Remove cable from housing and clean both
d. Try to prevent stepping on cable housing.

E. Safety procedures

Remind students that the AEC requires the use of an operating survey meter to determine position or location of source capsule. There are no alternatives to this requirement.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Use the following procedures to create discussion of the topic:

A. Have each student detail and construct a chalkboard sketch of the type of materials he would use and the safety features he would employ in the construction of an "ideal" camera. Have students justify each item as it is developed.

B. Invite other students to constructively criticize the construction designs and demonstrate how they would improve them.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. List the common shielding materials in the increasing order of their shielding ability per unit mass.

B. What is the prime disadvantage of reliance on devices which are designed to indicate the location of the source in remote handling equipment?

C. What is the best device for determining if the source is extended or shielded?

D. Describe the procedure for maintaining remote controlled devices. What is the most important item to consider in the inspection?

E. What are the possible consequences of worn locking devices on detachable control cable exposure units?

Check and discuss

V. SUMMARY

A. Exposure device shielding materials are usually lead, tungsten, or depleted uranium. Depleted uranium is the most efficient but is expensive.

B. All exposure devices have locking mechanisms. This is an AEC requirement.

C. All exposure device designs must be approved by the AEC. This is to assure that devices do not create a radiation hazard.

D. Webbed metal flexible tubes, plastic hoses and aluminum tubes are used to contain the drive cable and source capsule while exposures are being made. These can all be damaged easily thus creating a radiation hazard.

E. Safety lights, flags, arrows, and odometers are helpful safety tools but are not foolproof. A properly operating survey meter must be used whenever the source is moved from its locked storage position.

The Next Lesson is: Gamma Ray Exposure Devices

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 16
Lesson 8
Time 2 hours

SUBJECT: Gamma Ray Exposure Devices

AIM (or purpose): To further the understanding of the various types of gamma ray exposure devices available to the radiographer

TEACHING AIDS: Photographs of various devices
All available gamma ray exposure equipment

REFERENCES: Manufacturers literature
Industrial X-ray Handbook, Allan Lytel, 1962, Howard W. Sams Co. Inc., Indianapolis, Indiana
Information Sheets #42 and #43

I. PREPARATION (of the learner)

Write aim of lesson on chalkboard and develop student interest by pointing out that certain design features have been adopted to better suit the gamma ray exposure device to a specific job. A particular type of device may be many times more efficient in the performance of a unique or specific task. The radiographer should be aware of the advantages and disadvantages, the limitations and attributes of each type of device. There is no universally best type exposure device. Knowledge of the types that are available can be a valuable asset to the radiographer when selecting a particular type equipment for a specific type of job.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Remote controlled portable units 1. Crank extension 2. Crank shutter 3. Pneumatic 4. Snorkels	1. Issue information sheets #42, and #43 and display available types of gamma ray equipment. 2. Demonstrate the operation of the equipment.

	3. Explain the principles of operations and construction using the chalkboard: a. A source capsule attached to a cable and cranked in and out of the storage capsule b. A shutter that is remotely opened and shut in a crank shutter-type of device c. A source capsule that is moved through a flexible tube pneumatically d. A source that is raised and lowered inside an aluminum tube with a nylon string is the snorkel type 4. Display photos of other types of devices. 5. Outline the scope of operations performed with these devices on chalkboard. 6. Indicate the maximum activity of the materials which are generally loaded into these devices i.e., 30 to 100 curies of iridium 192.
B. Fixed and semi-portable units 1. Lab units 2. Wheeled mountings	1. Display photos of large fixed installations and semi-portable wheel mounted units. 2. Explain the method of manipulating the source and the safety devices of large fixed exposure devices. 3. Outline the scope of operations performed with these devices and how they are used for radiographing thick, dense materials, usually with cobalt 60 which requires heavier shielding than iridium 192.
C. Hand cameras 1. Hinged shutter 2. Rotating shutter	1. Display available hand cameras. 2. Show photos of other hand camera units. 3. Outline the scope of operations with these devices and how they

are used mostly for panoramic shots and pipeline radiography.

4. Indicate the activity of the materials generally loaded into these devices i. e., about 30 curies of iridium 192.

D. Personnel exposure from portable exposure devices

1. Describe the radiation conditions which exist when a source is extended from a remote control camera pointing out that there is little or no shielding surrounding the capsule while exposure is being made.
2. Describe the radiation conditions that exist while using a hand camera and that a large percentage of the source capsule is shielded while the exposure is being made.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Display available devices and illustration of devices and invite students to ask questions.

B. Ask for descriptions of the various types of portable remote control equipment that is available.

C. Suggest that students outline the scope of work performed with these devices.

D. Have them describe the construction and uses for various hand cameras.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What is the probable maximum amount of cobalt 60 which can be safely loaded and handled in remote controlled portable exposure devices?

B. What is the maximum amount of iridium 192 generally supplied in remote controlled portable devices?

C. Describe an exposure condition where a hand camera would be of more value than a portable remote extension unit.

D. Why is a portable remote extension unit best suited for work on construction sites?

E. Compare the radiation hazards of hand cameras and remote controlled extension units if both contained the same source.

V. SUMMARY

A. Remote controlled portable exposure devices can increase production because the relatively heavy body of the exposure device does not have to be repositioned with each exposure.

B. Remote controlled devices usually require more surveillance during exposures because of the large radiation field they create.

C. Fixed and semi-portable units usually use cobalt 60 as the source of radiation. Cobalt 60 requires much more shielding than does iridium 192.

D. Hand exposure devices are popular in shop work where space is at a premium and where workers are operating in the area will not be endangered. Hand exposure devices are also used extensively in pipeline construction due to their portability.

The Next Lesson is:Preparation of a Remote Controlled Gamma Ray Camera for an Exposure

INSTRUCTOR'S LESSON PLAN
Manipulative Skills

Unit 16
Lesson 9
Time 4 hours

JOB (or operation): Preparation of a Remote Controlled Gamma Ray Camera for an Exposure

AIM (or purpose): To develop skill in the setup and assembly of the components of a gamma ray exposure device

TOOLS AND EQUIPMENT: Remote controlled gamma ray exposure device
Gamma radiation survey meter

TEACHING AID Exposure facility or restricted area

REFERENCES: Manufacturers instruction manuals

I. PREPARATION (of the learner)

A. Write aim of lesson on chalkboard - explain the importance of developing skill in the set up and assembly of the components of a gamma ray exposure device.

B. Explain that the proper procedures and safety precautions are essential in the assembly of an exposure device when preparing for radiographic operations. Improper procedures may result in the detachment of the source from the cable and cause serious exposure to the radiographer. Care must also be exercised to avoid damage to cables and extension tubes which can result in the improper lodging of the source in the extended position.

II. PRESENTATION (of the skills)

Operations or Steps	Key Points (things to remember to do or say)
A. Demonstrate 1. Placement of camera	1. Select an area free from obstructions and entanglements for the placement of the camera. 2. Place camera on a solid level surface.
2. Extend control cables	1. Extend cables with the crank away from the anticipated area of exposure. 2. Extend cables without kinks or loops
3. Energize survey meter	1. Turn on survey meter, wait for warm-up and zero meter. 2. Keep survey meter in clear view throughout the remainder of the operations.
4. Connect control cables to camera (Some cameras may have permanently attached cables)	1. Extend extension cable from sheath approximately six inches. 2. Caution: Do not drop or lay extended cable in the dirt. 3. Remove cover from source pig-tail port. 4. Connect cable to pig-tail. 5. Caution: Check to insure that the connection is properly made and free acting. 6. Bring cable sheath forward by cranking extension handle. 7. Connect sheath to camera.
5. Connect extension tube to camera	1. Select only the amount of tube length required to perform the job. 2. Firmly attach tube to camera (Tubes may have snap, quick twist, or screw-type connectors). 3. Attach end cap, source switch, or collimator to free end of tube.

	4. Extend tube to object to be radiographed. 5. Remove all kinds and loops from the tube using tape to support it if necessary.
6. Unlock the camera	1. Retract the source as far as possible by reverse cranking on the handle. 2. Caution: Do not force crank. Use only enough pressure to insure source is in the fully retracted position. 3. Place key in lock and unlock the source.
7. Extension and retraction of the source	1. Turn crank to extend until source is firmly against the end of the tube. 2. Make desired exposure. 3. Turn crank to retract source until source is firmly against stop in the camera. 4. Observe the survey meter to insure source is in the safe position. Approach camera with caution using survey meter to insure source in actually in the safe position.

III. APPLICATION (practice by learner under close supervision)

A. Divide the class into two groups and have one group instruct the other in the proper techniques while the second group performs the instructed operations.

B. Reverse the groups and repeat.

C. Supervise the students very closely to insure development of sound practices and safety procedures.

D. Stress very strongly the proper and constant use of the survey meter.

E. Invite questions and promote sound discussion whenever possible.

IV. TEST (performance of skill to acceptable standards)

Test each student determining that he can perform the proper technique of camera setup for gamma radiography. Have him state his intended actions before performing the next step. The student should explain the reasons for each of his actions as he progresses.

V. SUMMARY

A. No exposure is to be made without having a properly operating survey meter at the job site.

B. Survey meter must always be used for each individual exposure to make certain that the radioactive source is in a safe or controlled position.

C. Planning each exposure set-up beforehand will save a lot of steps and a lot of unnecessary lifting.

D. Personnel monitoring equipment and radiation warning signs must be used at all times while making exposures or handling radioactive materials and equipment.

The Next Lesson is: Radiography with Unattached Gamma Ray Sources

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 16
Lesson 10
Time 1.5 hours

SUBJECT: Radiography with Unattached Gamma Ray Sources

AIM (or purpose): To develop a working knowledge of the techniques for handling gamma source capsules

TEACHING AIDS: Magnetic source handlers, radioactive capsule and shield

MATERIALS: Paper cups
Tape

REFERENCES: Information Sheet #44

I. PREPARATION (of the learner)

A. Develop student interest by discussing the fact that the Atomic Energy Commission allows the use of a maximum of 1 curie of cobalt 60 and 3 curies of iridium 192 without an exposure device providing that a 1" x 1" metal tag is permanently attached to the capsule with stainless steel wire. The tag is colored magenta and yellow, has the standard radiation warning sign on one side and contains the following notice on the opposite side: "Warning - radioactive material - do not handle - if found notify civil authorities".

B. The use of these sources is becoming obsolete in radiography particularily with the advent of the crankout type exposure devices. Many incidents have occurred in the past when these type of sources were left unattended in shop and field operations. A well trained radiographer should be familiar with all types of operations involving radioactive material and especially the safety precautions related thereto.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The unattached gamma ray source	1. Briefly outline this practice referring to Information Sheet #44: a. A paper cup is taped to an object and the specimen to be radiographed is placed a pre-determined distance from cup. b. Source storage shield is unlocked and capsule is removed and placed in paper cup with a magnetic source-handling rod about eight feet long. c. Source is replaced in storage shield and shield locked after exposure has been made. 2. Tag attached by a length of wire to the capsule is usually kept hanging outside the storage shield to facilitate handling of capsule with magnetic handler. If necessary, a nylon cord attached to the tag can be attached to a pole to remove the capsule.
B. Handling precautions	1. Exposure to radiation by the radiographer can be calculated before the actual exposure is made. 2. Care must be taken to prevent damage to the source capsule as this could create a serious contamination problem. Explain at length. 3. Source storage shield cavity and plug have offsets in their diameters to prevent radiation from passing between cavity and plug. (Illustrate this on chalkboard) 4. A bright colored tag attached to capsule is an aid in locating a lost capsule.

5. Remember, if you can read the printing on the tag then you are probably too close to the capsule.

C. Advantages and disadvantages

1. An unattached source can be used to advantage when working in a relatively inaccessible area such as between two rows of boiler tubes.
2. This type source creates a hazard if dropped from a structure or into a stream where it would be difficult to retrieve.
3. Source of this type also creates an environmental hazard in the possibility of overexposure.
4. These sources usually represent a considerable saving in that costly exposure devices are not required and the storage shields used with unattached sources are relatively inexpensive.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Ask students to cite situations where free sources could be used to advantage giving a full and thorough explanation of each condition.

B. Have students explain the approved methods for handling free sources.

C. Suggest that students:
   1. Outline the safety hazards associated with handling free sources.
   2. State the advantage of using free sources.
   3. Discuss the disadvantages of using free sources.

D. Simulate using a free source and have each student perform the operation. Discuss their techniques and make corrections if necessary inviting all questions as they arise.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. List three advantages of radiography with free sources.

B. Give three disadvantages.

C. What is the chief cause of the decline in the use of free sources?

Check and discuss.

V.: SUMMARY

A. Gamma ray sources used without an exposure device have had a long history of incidents involving overexposures to radiographers and workers near the area of operations.

B. This practice originally started with the use of radium as an industrial inspection tool. Regulations were non-existant during that time.

C. All safety precautions must be rigidly adhered to for this type of operation as well as for the more conventional methods.

D. With the advent of crankout and pneumatic type exposure devices, there is little justification for the use of the subject method.

The Next Lesson is: Changing Sources

INSTRUCTOR'S LESSON PLAN
Manipulative Skills

Unit 16
Lesson 11
Time 2 hours

JOB(or operation): Changing Sources

AIM (or purpose): To develop skill in the exchange of a depleted source with a new high activity unit

TOOLS AND EQUIPMENT: Remote control gamma ray exposure device
Source changer for the exposure device
Gamma radiation survey meter

TEACHING AIDS: Exposure facility or restricted area

REFERENCES: Manufacturers instruction manuals
Information Sheet #45

I. PREPARATION (of the learner)

When a source's activity has decayed to an unsatisfactory level, it is replaced in the camera by a more active source. This is done by returning the equipment to the supplier or by its exchange as performed by the radiographer. New sources are shipped in containers called source changers. Changing of sources is a simple operation if properly performed; however, a series of accidents have resulted from inexperience or negligence in source changing. The radiographer must master the techniques to avoid these accidents and this lesson is calculated to help the individual to attain this desired skill.

II. PRESENTATION (of the skills)

Operations or Steps	Key Points (things to remember to do or say)
A. Placement of camera and source changer	1. Demonstrate by selecting an area free from obstructions and entanglements for placement of equipment.

	2. Place camera and source changer on a firm level surface.
B. Energize survey meter	1. Turn on survey meter, wait for warm-up, and zero meter. 2. Note: The changing of sources is best accomplished by two people and the use of two meters is recommended. 3. Each man should keep a meter in clear view throughout the operation.
C. Set up camera	1. Follow standard procedures for connecting the cables. 2. Use one length of tube (Special tubes may be supplied with the changer) to connect camera to source changer. 3. Connect tube to empty cell of changer. 4. Check cables and tubes for freedom from kinks, loops, or tension.
D. Disconnect old source	1. Issue Information Sheet #45 and extend old source into empty cell of changer. 2. Place survey meter in view throughout the disconnect operation. 3. Disconnect source from cable very carefully. 4. Danger: Source changers generally do not have locking devices to hold the source while disconnecting. Exercise extreme care not to pull source from the shielded position while making connections. 5. Remove the extension tube and lock old source in place.
E. Connect new source	1. Connect the tube to the cell containing the new source. 2. Place survey meter in view throughout the connect operation.

3. Using the same caution as before, connect the new source to the cable.
4. Retract the source into the camera.
5. Lock the camera.
6. Survey the camera to insure the source is in the safe position.
7. Disassemble the camera and return it to storage.
8. Prepare source changer for storage or shipment.

III. APPLICATION (practice by learner under close supervision)

A. Have each student perform the instructed operations under the close supervision of the instructor.

B. Offer corrective suggestions, invite questions and repeat until all have performed the operation satisfactorily.

IV. TEST (performance of skill to acceptable standards)

A. Divide the students into groups of two. Each group must display the proper technique of camera setup, positioning of the source changer, and use of safety procedures while performing a change of sources. Have the students state their intended actions before performing the next step of their operations. Have students explain the reasons for their action.

B. Discuss and evaluate performance as tests progress.

V. SUMMARY

A. Same safety precautions necessary for source changing as when making an exposure.

B. Operation should not be performed by only one person as a second person is necessary to act as a monitor.

C. Source changers generally are not a safety locking device that can be used while sources are being exchanged.

D. Source changing operation should always be performed by using a written step procedure for each operation so that the proper sequence will be maintained.

The Next Lesson is: Focal Spot Size

EXPERIMENT SHEET
Focal Spot Size

Unit 16
Lesson 12
Time 4 hours

SUBJECT: Determining the Focal Spot Size of an X-ray Generator

NOTE:
Instructor performs all operations

INTRODUCTORY INFORMATION:

The size of the focal spot of an x-ray generator or the size of an isotope source has a great influence on the quality of the radiographs produced by the equipment. Occasionally the internal components of a tube will shift or become damaged altering the focal size and resulting in poor radiographic quality. Isotope sources are occasionally shipped in the wrong size for the job or specification intended. The radiographer should be able to determine when any of these unusual conditions exist.

MATERIALS AND EQUIPMENT:

X-ray generator or gamma source and exposure facilities
Film cassettes and film
Sheet of lead, 8" x 10" by .005" thick
Sheet of plywood 8" x 10" with 1" diam. hold in center
Dark room facilities
Hand drill and 1/64" drill bit
1-6 ft. measuring tape with 1/32" graduations
1-rule with millimeter scale

PROCEDURE:

A. Single load 5" x 7" film cassette with selected film and lead screens.

B. Set up x-ray generator or gamma source for exposure.

C. Set the film-focal distance at 24".

D. Drill a 1/64" hole through the lead sheet at exactly the center.

E. Place the lead sheet on a sheet of plywood or similiar materials in which a hole about an inch in diameter has been cut. Position the pin hole in the lead sheet in the center of the large hole.

F. Position the board and lead sheet directly under the source of radiation exactly half way between the film and the source. (approximately 12" distance from source)

G. Expose the film to a density between 1 and 1.5.

H. Develop the film at 68°F. for 5 minutes. Fix and dry.

I. Measure the image of the focal spot which appears on the developed film.

J. Add 1/32" to the dimensions obtained by measurement.

CONCLUSIONS:

A. The focal spot size of this machine is ________________.

B. The value of twice the pin hole size is added to the dimensions of the focal spot because of the __________ ____________ distance.

C. The value obtained from measurement ____________ (does/does not) compare favorably with the manufacturers data.

NOTE TO INSTRUCTOR:

If this experiment is performed with gamma rays,have one student process the radiographic film and continue with the same experiment using an x-ray generator.

The Next Lesson: Visit to a Pipeline or Process Construction Job

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 16
Lesson 13
Time 6 hours
(1 day)

SUBJECT: Visit to a Pipeline or Process Construction Job

AIM (or purpose): To permit the student to observe the construction and inspection of pipe, and to experience the hazards and rigors of pipe construction

MATERIALS: Film badges
Dosimeters
Safety glasses
Hard hats

I. PREPARATION (of the learner)

A. Before leaving for the field trip, the student should be instructed as to the reasons for the trip, its objectives, and the need for carefully observing the following operations:

1. The hazards of the construction, particularly the overhead handling of pipe, overhead welding, movement of heavy equipment, and the work at elevated positions
2. The welding of pipe in all positions
3. The care (or mishandling) of welding electrodes
4. The types of welding equipment employed
5. Methods of pipe alignment
6. Preheating and stress relieving practices
7. Weld bead preparation and cleaning practices
8. The types of inspections employed after completion of welding

B. Issue safety instructions to be followed while at the job site, particularly caution against watching the welders at work. Issue safety glasses, hard hats, and any other items that will be needed. Remind all students to behave as guests of the company and remain in the group under the guidance of the supervisor.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
Observations in the visited facility	Be sure that students are made aware that a test will be given on what was observed.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

After returning from the trip, ask the students to discuss:

A. Their opinion of pipe construction work

B. The possible source of defects in welded pipe

C. The method of handling welding electrodes and how this can affect the weld quality

D. How the pipe ends were aligned and how this could affect the x-ray film image

E. How the weld cleaning practices affect quality and possible improved methods of weld cleaning

F. The methods used for inspection

G. The special handling tools used by the inspectors

IV. TEST (final check on students' comprehension of material presented)

A. Instruct each student to prepare a detailed written report on the observations made during the plant tour. Suggest that he cover in detail all observations that will in any way affect the radiographers function either in the field of manufacture, fabrication, inspection, handling or testing.

B. Have them list any suggestions they may have for future field trips and how these trips may be made more fruitful or benificial to them.

C. Check each report and discuss the results with the group.

The Next Lesson is: Film Manufacturing Process

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 17
Lesson 1
Time 1 hour

SUBJECT: Film Manufacturing Process

AIM (or purpose): To emphasize the methods and controls used in the making of radiographic film

TEACHING AIDS: Film: The Inside Story, 32 mins., 16 mm, sound, Eastman Kodak Company, Rochester, N. Y.
Film projector and screen

I. PREPARATION (of the learner)
  A. Introduce the film giving its name, length and type. Ask the students to carefully observe the following:
    1. The layers of different materials which comprise the structure of radiographic film
    2. The functions of each layer of the radiographic film
    3. The chemicals used to produce a sensitized emulsion
    4. The care used to insure uniformity of the finished product
    5. The care used in handling of radiographic film.
    6. The fact that most x-ray film consists of seven layers of materials

  B. Advise the students that a test will be given after the film is shown and suggest that it be closely observed with this in mind.

II. PRESENTATION (of the learner)

Instructional Topics	Things to Remember to Do or Say
A. The Inside Story	Show the film.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)
  A. Review the film emphasizing these points in the discussion:
    1. The structural make up of radiographic film
      a. The film base
      b. The emulsion
      c. The surface gelation layer

2. The treatment of silver nitrate and potassium bromide to produce the sensitive silver bromide crystals
3. The extreme care exercised in making of film to insure freedom from defects in the finished product
4. The quality control checks used to insure uniformity of the finished product

B. In addition to reviewing the actual film content,some reference can be made regarding the need for continued careful handling of the product after it is received for use by the radiographer and the need for his being aware of expiration dates and film storage conditions.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What is the purpose of the plastic layer between the two emulsion layers of radiographic film?

B. What is the composition of the gelation layer in radiographic film?

C. What part does the emulsion perform in the exposure of a radiographic film?

D. Why is the radiographic film subjected to the various inspection by the manufacturer during the manufacture of the film?

E. What would be the consequences to the radiographic operator if the film did not react uniformly on exposure?

V. SUMMARY

A. Parts of this instructional movie were made under simulated conditions because the film cannot be exposed to white light.

B. It is possible for the resultant film speed to vary slightly from one batch of raw material used in the manufacture of the film to another.

C. When opening a new box of film,cut off a strip of the top or bottom sheet, or both, and develop without exposing it to check for film fog.

D. Always observe the manufacturing date on the box before accepting film.

The Next Lesson is: Characteristics of Radiographic Film

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 17
Lesson 2
Time 2 hours

SUBJECT: Characteristics of Radiographic Film

AIM (or purpose): To develop background information regarding the properties of industrial film and how these properties affect radiographic quality

TEACHING AIDS: Samples of coarse and fine grain film
Identical radiographs using different films

REFERENCES: Radiography in Modern Industry, 1958, Eastman Kodak Co., Rochester, N. Y.
Kodak Photographic Films and Plates for Scientific and Technical Use, Publication P-9, Eastman Kodak Co., Rochester, N. Y. (1960)
Characteristic curves of various films - Eastman Kodak Co.

I. PREPARATION (of the learner)

A. State the subject and relate its aim or purpose outlining briefly why film characteristics are so vitally important to the radiographer.

B. Explain that the lesson will prove to be an interesting and informative one, imparting some fundamental and basic information that will be of considerable help to all.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The characteristic curve	1. Refer to curves shown in text. 2. Explain by chalkboard sketches: a. The method of constructing a characteristic curve b. The coordinates of the curve c. The relationship between density and exposure

	3. Outline the differences in characteristic curves of different film, i. e., the differences in chemistry and processing. 4. Display typical characteristic curves.
B. Granularity	1. Define granularity on chalkboard as minute silver particles having a tendency to group together in relatively large masses. This is referred to as clumping. Coarse grain film exhibit this graininess more than fine grain film. The x-ray image is composed of countless minute silver grains. 2. Explain: a. The relationship of granularity to film speed b. The effect of increased radiation energy on graininess c. The granularity from fluorescent screens d. The relationship of development time to graininess 3. Compare a fine grain film with a coarse grain film on chalkboard.
C. Resolving power	1. Define and explain resolving power. 2. Explain the dependence of resolving power on the character of the emulsion.
D. Turbidity	1. Explain film turbidity and its relation to exposure. 2. Define as muddled or stirred up.
E. Inherent film contrast	1. Differentiate between inherent film contrast and subject contrast. 2. Film contrast is: a. The range of inherent grain sizes b. Its relation to density 3. Subject contrast is the ratio of radiation intensities passing through two selected portions of a specimen.

	4. Show the method of determining the contrast exaggeration from the slope of the characteristic curve.
F. Sharpness (Acutance)	1. Define film sharpness as detail of image not blurred. Refer to Figure 20, Page 27 Eastman Textbook. 2. Explain: a. The dependence of sharpness on the emulsion b. Why weak developer reduces sharpness 3. Explain why sharpness is more important than resolving power in radiography. 4. Sharpness also depends upon intimate film and screen contact.
G. Factors affecting sensitivity	Have students turn to Page 48, Eastman Textbook and explain the factors listed in Table VI.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Have all students:

A. Explain the construction of a characteristic curve,

B. Point out the information which can be derived from the curve. Have the student concentrate on speed and density gradient.

C. Explain film contrast and how to determine the density range which produces the maximum contrast.

D. Define granularity and how it is produced. Explain the techniques for minimizing "graininess".

E. Give a definition of sharpness.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. From the characteristic curves which have been discussed, determine the film with the maximum speed. (Curves are in textbook)

B. Above what approximate value of density will contrast exaggeration occur in Kodak AA film?

C. What range of density will give the best contrast using Kodak M film with lead screens?

D. What is graininess? What factors can be controlled to minimize graininess?

E. Define image sharpness. How does the character of the emulsion effect sharpness?

F. Have students work a problem involving the use of logarithm tables in figuring a change in film exposure time for a particular film by increasing the required relative density from 1.5 to 2.0.

Check and discuss.

V. SUMMARY

A. The characteristic curve is most important in selecting film to be used for any particular assignment.

B. Film grain size increases with film speed. Relatively small grain size is desirable.

C. Film resolving power depends upon the character of the film emulsion.

D. Film contrast is inherent. Subject contrast depends upon the shape or thickness variation of the specimen and on its density variation.

E. Spent developer causes a reduction in image sharpness.

F. When using intensifying screens, good contact with film is necessary for maximum sharpness.

The Next Lesson is: Radiographic Screens

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 17
Lesson 3
Time 2 hours

SUBJECT: Radiographic Screens

AIM (or purpose): To define the purpose, and mechanisms of intensification and the advantages and disadvantages of radiographic intensification screens

TEACHING AIDS: Lead and fluorescent screens

REFERENCES: Radiography in Modern Industry, 1958, Eastman Kodak Co., Rochester, N. Y.
Information Sheet #46

I. PREPARATION (of the learner)

A. After introducing the subject, make the following statement to create interest and discussion: The use of lead screens with radiographic film will decrease the required exposure time and reduce the adverse effects of scattered radiation on the film and lead screens can also improve image quality. Calcium tungstate screens reduce exposure time and the amount of the x-ray radiation beam absorbed by the film is less than 1% of the total. This means that more than 99% of the available energy is performing no useful purpose. Therefore, any means of increasing the amount of energy utilized for creating the image will increase the efficiency of the operation. Radiographic screens are used for this purpose.

B. Explain that it is not expected that these statements will either be understood or accepted as such but are being made to demonstrate the depth and scope of this particular lesson and what exactly is being proposed for coverage.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The purpose of screens 1. Intensification 2. Reduction of scattering 3. Preferential intensification	1. Outline on the chalkboard the possible reductions in exposure time which result from the use of lead or fluorescent screens. 2. Explain the reduction in scattering when lead screens are employed and the problems of scattering when fluorescent screens are used. Lead screens filter out or absorb soft primary radiation and secondary scattered radiation while fluorescent screens cause film blurring and fogging, particularily if intimate contact is not made and maintained with the film. 3. Define on chalkboard the conditions which may result in longer exposure times when lead screens are used. 4. Explain the preferential intensification of lead to the primary beam and filtering of scattered radiation.
B. Mechanisms of intensification	1. Issue Information Sheet #46 and explain the action of lead screens in producing electron emission and secondary radiation pointing out that a lead screens' reaction to radiation is in the form of electron emission while secondary radiation is absorbed by the lead. 2. Explain the light emission of fluorescent screens in that certain chemicals fluoresse and as they absorb x-rays or gamma rays they immediately emit light. The light intensity depending upon radiation intensity.
C. Disadvantages of screens 1. Film contact 2. False indications	1. Explain the effects of non-uniform contact between film and screens resulting in blurring and fogging.

3. Static electricity marks
4. Afterglow
5. Graininess
6. Cleanliness requirements

2. Show how to determine if screens contact is uniform. Tape cassette tightly but do not damage film.
3. Explain how false indications are generated by scratches on the screens. See illustration page 24, figure 19, Eastman Textbook.
4. Discuss the generation of static electricity and the marks it produces. Static marks are star shaped and usually occur in dry climates when cassette is thrown on work bench and if operator is wearing rubber soled shoes.
5. Outline the effect of afterglow from fluorescent screens. Afterglow in fluorescent screens blurs film.
6. Explain why fluorescent screens cause graininess and why graininess from fluorescent screens is independent of film grain size.
7. Demonstrate the necessity of keeping screens free from dirt, lint, and trash. (images of dirt will appear on radiograph and will tend to scratch the film. It will also contaminate developing chemicals.)

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Have students:

A. Explain the effects of using lead screens on the speed of exposure when employing 160 kv or more.

B. Explain the effects of lead screens on the definition of the radiograph.

C. List and explain the undesirable effects of intensifying screen usage.

D. Explain the phenomenon which results in intensification when using lead screens.

E. Explain why lead screens are not used at lower kv settings.

F. Explain why calcium tungstate screens are not used with gamma rays.

G. Place a calcium tungstate screen near a source of gamma radiation and have students observe the greenish glow emitted by the screen. Darken the room before exposing the screen. Observe all required safety precautions when conducting this demonstration. Ask students to explain the demonstration.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What happens when radiation passes through a thin sheet of lead placed in contact with a film in its exposure holder?

B. What is the most objectionable characteristic of fluorescent screen intensification?

C. What is afterglow and why is it objectionable?

D. Scratches, dirt, and lint between the film and the screen cause undesirable effects. Elaborate.

E. What is the effect of poor film to screen contact? How can the degree of contact be determined?

Check and discuss.

V. SUMMARY

A. Lead intensifying screens are usually used at radiation intensities above 125 kv.

B. Calcium tungstate screens are for x-ray use only.

C. Lead screens speed exposure time by electron emission.

The Next Lesson is: Loading of Film Cassettes

INSTRUCTOR'S LESSON PLAN
Manipulative Skills

Unit 17
Lesson 4
Time 1 hour

JOB (or operation): Loading of Film Cassettes

AIM (or purpose): To assist the student in the development of skills and the proper techniques of handling film, screens and cassettes

MATERIALS:
- Film
- Trichloroethylene
- Cheese cloth
- Very fine steel wool

TEACHING AIDS:
- Film cassettes
- Intensifying screens

REFERENCES: Radiography in Modern Industry, 1958, Eastman Kodak Co., Rochester, N.Y.

I. PREPARATION (of the learner)

Write aim of lesson on chalkboard and stress the need for this effort in that proper handling, loading, and care of film cassettes and screens is essential to production of high quality radiographic film. Use of proper handling procedures and high quality work are characteristics of competent radiographers and an individual will prosper and succeed in direct proportion to how well he can perform the total task. Making a first class exposure is not enough if the film is damaged or destroyed through improper handling.

II. PRESENTATION (of the skills)

Operations or Steps	Key Points (things to remember to do or say)
A. Demonstrate in lighted room preparation of loading area	1. Clean work bench space of all objects in the area particularily where film is to be loaded

	2. Wipe top of work bench with damp cloth to remove all dirt and lint. 3. Dry bench top with dry cloth 4. Rub top of bench with palm of hand to insure freedom from grit and dirt.
B. Collect materials	1. Select cassettes, screens, and film to be used in loading. 2. Place each component in convenient position for assembly. 3. Stand film box upright against backboard behind work area.
C. Examine cassettes and screens	1. Open cassettes and inspect for lint or dirt. If necessary clean them with a damp cloth and dry thoroughly. 2. Examine screens for lint, dirt, excessive oxidation, scratches, or creases. 3. If necessary clean oxide from lead screens with cloth wetted in trichloroethylene. Dry thoroughly. Heavy concentrations of dirt and oxidation may be removed by light rubbing with very fine steel wool. 4. Caution: Use only recommended solvents and never use an abrasive on fluorescent screens. 5. Discard screens with creases. 6. Examine screens to insure that intimate contact can be made over the full surface.
D. Assemble components	1. Place screens in cassettes with cassettes flat and open on the bench. 2. If a thicker screen is to be used on one side, be sure that the screen is on the back side of the cassettes.

E. Load film

1. Remove film from the box one at a time.
2. Remove interleave from film.
3. Hold film by the edge and lay on screen opposite the flap of the cassettes.
4. Caution: Avoid crimping, sliding, fingerprinting or scratching the film.
5. Lay other screen on film without sliding.
6. Close cover, tape or lock.

III. APPLICATION (practice by learner under close supervision)

A. Have all students practice film loading while room is lighted, using old developed film.

B. Have all students practice film loading in dark room with only safe light illumination still using old developed film.

C. Give close supervision throughout, inviting all questions and repeating any procedure that is the least doubtful.

IV. TEST (performance of skill to acceptable standards)

NOTE: Performance Test

A. Collect cassettes, screens and undeveloped film on the work bench. Have each student load one cassette in total darkness from the disassembled layout.

B. Check results and discuss repeating operation where unsatisfactory results were obtained.

V. SUMMARY

A. Good Housekeeping in film loading room is absolutely necessary to prevent film artifacts.

B. Preliminary steps can be taken before white lights are extinguished.

C. Cassettes should be marked top and bottom so that proper thickness screen is on the proper side.

D. Screens are sometimes used on one side only.

The Next Lesson is: The Photographic Process

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 17
Lesson 5
Time 1.5 hours

SUBJECT: The Photographic Process

AIM (or purpose): To acquaint the students with the chemical reactions which occur in the process of producing a radiograph

REFERENCES: College Chemistry, Sinko and Plain, 1966, McGraw-Hill Book Co., New York, N. Y.
Negative Making - with Kodak, Blank and White Sheet Films, Kodak Publication No. F-5-1962, Eastman Kodak Co., Rochester, N. Y.

I. PREPARATION (of the learner)

A. Develop student interest in the proposed subject by pointing out that the sole purpose of the lesson is to assist the radiographer in doing quality work.

B. While a knowledge of the chemical processes of film exposure and development is not absolutely essential to the production of darkened film, this knowledge is essential if the radiographer desires to maintain the highest possible level of quality workmanship.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. The emulsion 1. Gelatin 2. Chemical composition 3. Sensitive collodial suspension 4. Grain size	1. Explain the purpose of the gelatin: a. Acts as a vehicle which silver bromide crystals are distributed b. Crystal distribution must be uniform for dependable radiographs c. It has properties which increase silver bromide (AgBr) sensitivity to radiant energy

2. Outline on the chalkboard the process of mixing chemicals to form the sensitive collodial suspension:
   - a. Start with a flexible cellulose derivitive base coated with an adhesive sub-coat which binds emulsion firmly to base.
   - b. Film coated on both sides to increase speed
   - c. Film consists of seven layers; cellulose base, adhesive on both sides, emulsion on both sides, protective coating on both sides
3. Write the chemical equation for the reaction on the chalkboard, i.e., $AgNo_3 + KBr = AgBr + KNO_3$
4. Explain the light-sensitive characteristics of silver bromide.
5. Explain the relationship between grain size and holding time of the suspension.

B. Exposure and the latent image

1. Explain the tendency of AgBr to decompose to free metallic silver when exposed to radiation.
2. Relate the amount of decomposition to the amount of exposure.
3. Ask questions.

C. Developing

1. Explain the reduction of AgBr by the developer to form black metallic silver.
2. Relate the film density to the extent of decomposition on exposure and the amount of AgBr converted on developing.
3. Define the time dependence of the developing process.

4. Caution against over development and the reduction of all silver to the metallic form.

D. Fixing

1. Explain the presence of unaffected AgBr left in the film after developing and its sensitivity to radiation and light.
2. Outline the reaction between the fixer (sodium thiosulfate) and the unexposed AgBr to form water soluble silver thiosulfate ions.
3. Explain and discuss the time dependence of the fixing reaction.
4. Define the action of hardeners.

E. Washing and drying

1. Explain the necessity of washing to remove the soluble silver ions from the film.
2. Stipulate the time and temperature requirements of washing for adequate removal of the silver ions.
3. Explain and discuss the drying process necessary to put the film in condition for handling and storage:
    a. Remove excess moisture from film
    b. Vent drying cabinet
    c. Do not overheat film
    d. Clean, warm, dry air necessary

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Have individual students explain and illustrate when possible:
   1. The composition of the emulsion
   2. The exposure process and the chemical reactions that occur
   3. The chemical process of development
   4. The chemical process of fixation

B. Question to promote discussion:
   1. What is the result of prolonged over-development?
   2. What happens to the unaffected silver bromide crystals if film is exposed to light before fixation?
   3. How are solvable ions removed from film? Why?
   4. Why is film washed before drying?
   5. What effect does humidity have on film drying? How can it be reduced?

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. Define the sensitive chemical compound in film emulsions.
B. What occurs when radiation strikes the emulsion?
C. Describe what takes place in the developing of film.
D. What happens to the film if it is left in the developer for an amount of time longer than necessary to develop the latent image?
E. Define the element that forms the black image on the film?
F. What occurs when the film is fixed?
G. Why is it necessary to wash the film after fixing?
   Check and discuss.

V. SUMMARY

A. Radiographic film normally consists of seven layers of materials; three layers on each side of the base material.

B. Silver bromide crystals are light sensitive and are sensitive to radiation.

C. The latent image of a specimen is formed by the decomposition of silver bromide to free metallic silver.

D. Fixation and hardening are necessary for the removal of undeveloped silver salts and the hardening of the gelatin so it will withstand drying with warm air.

E. Washing diffuses and washes off the fixer.

The Next Lesson is: Film Artifacts

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 17
Lesson 6
Time 2 hours

SUBJECT: Film Artifacts

AIM (or purpose): To develop an understanding of the various unsatisfactory conditions which occur in radiography, the causes of these conditions, and how they are eliminated

TEACHING AIDS: An assortment of damaged film

REFERENCES: Radiography in Modern Industry, 1958, Eastman Kodak Company, Rochester, N. Y.

I. PREPARATION (of the learner)

A. After introducing the subject of the lesson, point out that nothing reflects more on the abilities of a radiographer than the production of poor quality film, even though the poor quality may be the result of a variety of causes and many circumstances other than poor workmanship. Conditions quite often arise which change the quality level of the film and the radiographer must learn to recognize these conditions in order to be able to correct the cause and bring the level of quality back to normal.

B. This lesson will deal with the abnormal qualities that can affect the quality of film adversely and its importance is relatively self evident.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Incorrect density	1. Explain the conditions which can result from incorrect exposure.
1. Over or under-exposure	
2. Over or under-development	
3. Depleted developer	2. Describe the latitude in density which can result from developing procedures. Explain how changes

	in development can be beneficial as well as harmful. 3. Display sample film.
B. Incorrect contrast 1. Radiation quality 2. Over or under-development	1. Outline the effects of improper penetration characteristics on film contrast. 2. Describe the effects of development procedures on contrast. 3. Display sample film.
C. Poor sensitivity 1. Geometric factors 2. Film factors	1. Outline the methods of adjusting exposure dimensions to improve definition. 2. Review the effects of a large focal spot on film sensitivity. 3. Review the problems in the use of radiographic screens. 4. Examine the choice of film for the job being performed. 5. Display sample film.
D. Fog 1. Light leaks 2. Radiation leaks 3. Improper safe lights 4. Heat, humidity, and vapors 5. Improper darkroom procedures	1. Describe the effect on film when exposed to light or radiation leaks. 2. State the desired characteristics of a safe light and detail the consequences of improper handling of film under safe light condition. 3. Explain the effects of atmospheric conditions on film fogging. 4. Describe the dark room procedures which result in fogging. 5. Display sample film.
E. Streaks and stains 1. Film hangers 2. Poor chemical agitation 3. Elimination of stop bath 4. Elimination of wetting agents 5. Spent chemicals	1. Explain why dirty film hangers cause streaks. 2. Describe the effects of improper agitation of developer, stop bath, and fixer on stains and streaking. 3. Explain why the elimination of stop bath and wetting agents cause streaking. 4. Describe the staining of film from the use of depleted chemicals.

	5. Display sample film.
F. Mechanical film defects 1. Damage to emulsion a. Loosening b. Scratching 2. Crimp marks 3. Static marks 4. Air bells 5. Dirt in cassettes	1. Describe the conditions which cause each of the listed defects. 2. Explain how these conditions are eliminated. 3. Display sample film.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Have all students separate the sample film into groups representing:
   1. Improper techniques
   2. Improper darkroom practices
   3. Mechanical handling defects

B. Suggest that they identify the source of the defects in each category.

C. Have them explain how each defect can be eliminated.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What is the cause of light and dark streaks on film which has been developed using hangers?

B. What causes streaks at the top corners of film which has been processed while suspended on film hangers?

C. How can a radiographer determine if a crimp mark was made before or after exposure?

D. How is a static mark identified? Eliminated?

E. What happens to film that is washed for prolonged periods in warm water? Why?

F. Describe the effect of fogging on sensitivity? Why?

G. How can a radiographer determine when the darkroom chemicals need replenishing or replacing?

H. What causes air bells? How can they be eliminated?

Check and discuss.

V. SUMMARY

A. Correct optimum film density is seldom achieved.

B. Film contrast can be improved with correct developing procedures.

C. Good film sensitivity depends upon proper geometry of exposure set-up, proper film screens and the proper film.

D. Film fog is caused by age of film, heat, light leak, over-developing, improper safe lights, humidity, vapors, etc.

E. Other film or artifacts are streaks, stains.

F. Mechanical defects include damaged emulsion, static marks, dirt in cassettes, etc.

The Next Lesson is: Care and Handling of Radiographic Film

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 17
Lesson 7
Time 1.5 hours

SUBJECT: Care and Handling of Radiographic Film

AIM (or purpose): To teach the correct techniques for care and handling of radiographic film

TEACHING AIDS: Film boxes
Film with interleaves
Film storage envelope

REFERENCES: Radiography in Modern Industry, 1958, Eastman Kodak Co., Rochester, N. Y.

I. PREPARATION (of the learner)

Since radiographic film is highly sensitive and easily damaged. It is necessary to consider the subject of care and handling film. Radiographic film is sensitive to light, heat, moisture, some gases, radiation and physical strain. The best radiographic techniques can be rendered worthless if the film is damaged before, during, or after processing. To avoid this waste in time, energy, and money, a knowledge of film handling practices is most essential and in some instances mandatory.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Opening of film boxes	1. Demonstrate the operation. 2. Explain the function of the inner pack or seal (keeps out moisture) 3. Caution against rapid withdrawal of film from the box and explain static marks. 4. Recommend removal of the film in the interleave to avoid scratching.
B. Loading and handling cassettes	1. Recommend the loading of film in the interleave when screens are not employed.

2. Explain why the film cannot be loaded in the interleave when using screens; Interleaf image appears on radiograph.
3. Caution against abrasion of film in loading.
4. Describe the strain damage to film caused by excessive bending or pressure on the cassette or exposure holder.

C. Storage of film

1. Explain the ideal storage facility, such as the film storage cabinet in the darkroom.
2. Explain the desire for:
   a. Controlled temperature and humidity
   b. Controlled environment
   c. Light tightness
   d. Radiation shielding to prevent fogging
3. Recommend a film supply equal only to requirements.
4. Explain the desirability of maintaining a stock rotation plan.

D. Dark room handling

1. Use oldest film first.
2. Explain and display film damage from:
   a. Improper attachment of film to hangers
   b. Overloading tanks
3. Explain why the temperature of the drying process must be controlled.
4. Excessive humidity and heat affects film quality and film drying time.
5. Explain the necessity of corner removal on processed film, because it removes corner clip holes and sharp edges that scratch other film.
6. Recommend the utilization of interleaving for storage of processed film as it prevents film abrasion.
7. Display the recommended edge seal envelope for processed film storage.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Have all students:

A. Explain the procedures, precautions and whys for opening and handling of boxed film.

B. Outline the techniques for loading film cassettes, employing paper interleaving, and the avoidance of strain damage.

C. Describe the ideal film storage area and explain the reasoning behind the design.

D. List three operations in the darkroom where film may be damaged.

E. Describe the procedure for the storage of exposed film.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What is the purpose of the paper interleave found in new film packages? How can it be used to advantage after the box is opened for use?

B. What type of film defect can result from very rapid withdrawal of film from the package?

C. List four operations of film handling where emulsion strain is likely to occur.

D. Why is it best to keep only a limited amount of film in storage?

E. What is the purpose of corner cutting after the drying of film?

Check and discuss.

V. SUMMARY

A. Care must be taken when removing unexposed film from container to prevent static marks on film and to keep sharp corners of film from damaging other film.

B. Interleaving paper prevents abrasion and can be left on film if screens are not being used in cassettes.

C. Film storage includes proper inventory to prevent ageing of film; protection from x-ray and gamma radiation and protection from excessive heat.

D. Interleaves should be used in storing processed film.

The Next Lesson is: Multiple Film Exposure

EXPERIMENT SHEET
Multiple Film Exposure

Unit	17
Lesson	8
Time	4 hours

SUBJECT:

The radiographic inspection of parts or materials with high subject contrast due to shape of the part

NOTE:

Instructor performs all operations

INTRODUCTORY INFORMATION:

When a part must be inspected which has two or more areas of varying thickness, selection of the proper film involves a critical analysis to determine the density at the thickest and thinnest areas of the part. If the density of the film in these areas cannot be maintained within the limits desired for a single film, multiple exposures are required to achieve the desired results. To avoid the time consumption of multiple exposure, techniques may be used to achieve the desired results in a single exposure. Developing skill in the use of these techniques is the purpose of this experiment.

MATERIALS AND EQUIPMENT:

Gamma ray or x-ray source and exposure facilities
Film cassettes and film
Survey meter
Densitometer
Penetrameters, lead numbers, and shims
Characteristic curves of film
Sample parts
Darkroom facilities

PROCEDURE:

A. Measure the thickness of the part at the maximum and minimum areas. Determine the ratio of the thicknesses.

B. Examine film types to determine if a suitable film is available for a single film inspection.

C. Use characteristic curves to determine the difference in the relative exposure to maintain the density limits between 1.5 and 3.0.

D. If a single sheet film cannot be used, select a slow speed film for the thin section of the part. The film should be selected to be given an exposure for a density of 2.0.

E. Examine the characteristics of other film to determine which possesses a speed, at a density of 2.0, relative to the first equivalent to the ratio of the thicknesses from the maximum and minimum areas.

F. Load suitable film cassettes with one film of each type and appropriate screens. Use only two screens placing one screen on each side of the film sandwich.

G. Transport the equipment to the exposure site.

H. Select desired exposure conditions and erect equipment.

I. Setup film for exposure using 2-2T penetrameters for each thickness to be examined. Place penetrameters on shims of equal thickness if placement cannot be made directly on the part.

J. Mark the film with appropriate numbers for identification.

K. Calculate the exposure time to produce a density of 2.0 on the slower film and the thinnest section. Check the density which will result from exposure of the faster film in the thicker section. The density should be between 1.5 and 3.3.

L. Energize the survey meter, wait for warmup, and zero meter.

M. Perform exposure, survey equipment, and secure in safety condition.

N. Develop film for 5 minutes at 68°F., fix, wash and dry.

O. View each film individually in the areas of the part where the density and sensitivity meet the required limits.

P. Measure the density of each film in the areas of interest.

CONCLUSIONS:

A. The maximum thickness ratio which could be tolerated under these limitations if Kodak AA and M film were used is __________.

B. This technique ________, ___________, or ___________ be used with only one type film even though the density could not be maintained within limits on a single sheet of film. Explain.

C. The density of each film_________ or ______the value expected from the exposure calculations.

The Next Lesson is: Darkrooms

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 18
Lesson 1
Time 2 hours

SUBJECT: Darkrooms

AIM (or purpose): To acquaint the student with construction features of portable and stationary darkrooms

REFERENCES: Nondestructive Testing Handbook, Volume I, 1963, Society for Nondestructive Testing, Evanston, Illinois
Information Sheet #47 and #48

I. PREPARATION (of the learner)

A. Explain that it is sometimes necessary to improvise a temporary field darkroom, and a knowledge of the basic requirement of such a facility would be most helpful. It would be beneficial to know what problems occur when operating from portable darkrooms that generally do not occur in stationary facilities.

B. This lesson will also provide a thorough study and consideration of all construction features whether they are used in portable or fixed installations.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Stationary darkrooms	1. Issue information sheets #47 and 48.
1. Layout	2. Describe the area requirements by the planned volume of work to be performed. 3. Explain the desirability of separate loading and processing rooms for large work loads. 4. Discuss and explain the necessity for keeping the wet functions separate from the dry as it prevents damaging of the film.

2. Construction	1. Explain the desirability of using chemical resistant paints on smooth finished walls since photographic chemicals attack ordinary house paint. 2. Elaborate on the necessity for tile, stainless steel or plastic coverings around the processing tank area -- to combat corrosive chemicals. 3. Describe suitable floor coverings again stressing chemical resistant materials. 4. Draw chalkboard sketches of maze type entrance and light lock. 5. Explain the necessity for stainless steel or plastic plumbing-to combat corrosive effect caused by chemicals. Give examples. 6. Explain the function of water line check valves which are installed in automatic cooling lines preventing reverse flow contamination.
3. Processing tanks	1. List the desirable tank construction materials--some types of stainless steel, plastics, hard rubber or fiberglass. 2. Define the ideal water temperature control system. Controls at 68° - 72°. 3. Outline the desirable capacity ratio for developer, stop bath, fixer, and wash tanks. No less than 5 gallons each and 10 gallon for wash.
4. Dryers	1. Explain the necessity for adequate capacity so film won't touch and stick. 2. Describe the desirable features; i.e., timer, heat and fan controls, drip pans, etc.

5. Illumination

1. Outline the requirements for illumination.
2. List the restrictions on brightness:
   a. Filtered light fixtures positioned so film will be handled at least 4' away
   b. 15 watt bulbs and Wratten filters except for extremely light sensitive film use 7 1/2 watts.
3. Describe the method of checking to determine if the room is over-illuminated:
   a. Cut piece of film in two
   b. Develop one piece
   c. Check density
   d. Place other piece on table top for an hour
   e. Develop second film
   f. Check density
   g. Compare the two films

B. Portable Darkrooms

1. Describe a typical portable darkroom in terms of size and method of construction, see information sheet #46 (both sides).
2. Explain the necessity for additional care when working in the restricted space of a portable darkroom:
   a. Danger of damaging developed, unexposed film
   b. Film must be protected if gamma exposure device is stored in darkroom
3. Discuss and explain the problems of entrances, cleanliness, sealing of tanks, maintenance of chemical temperature, drying of film, tank capacity, environmental temperature control, water supply, power supply, etc.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Have students:

A. Describe the layout and facilities for the processing of several hundred hangers of film per day.

B. Outline the requirements and restrictions of darkroom illumination.

C. Discuss the available construction materials for processing tanks.

D. Describe the materials for protection of floors and walls of darkrooms.

E. Compare portable field darkrooms with stationary installations and discuss the additional problems of working from portable darkrooms.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. Draw sketches of two types of entrance ways for stationary darkrooms.

B. Why are processing tanks usually made from stainless steel?

C. Why are check valves on processing tanks and water lines desirable and required by many city regulations?

D. List three problems of field darkroom construction which are not found in stationary facilities. Explain how these are overcome in field installations.

E. What is the safe distance from exposed film for a 15 watt bulb when used in an acceptable safelight holder with a filter?

Check and discuss.

V. SUMMARY

A. Portable field darkrooms are usually not as desirable as fixed installation. This is due mainly to an inadequate wash water supply and the problem of maintaining temperature control of the chemicals.

B. Darkrooms should be planned to provide a "dry" side for film loading and unloading and a "wet" side for film processing.

C. Film processing chemicals are corrosive and precautions must be taken to counteract this problem when designing darkroom facilities.

D. Portable facilities have much greater inherent problems in combating the effects of corrosion by film-developing chemicals.

The Next Lesson is: Darkroom Housekeeping

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 18
Lesson 2
Time 1.5 hours

SUBJECT: Darkroom Housekeeping

AIM (or purpose): To develop an appreciation for maintaining clean safe facilities and the care of clothing and skin

TEACHING AIDS: Plastic gloves and apron
Film hangers which have been cleaned and some which require cleaning

MATERIALS: Commercial process tank cleaners

REFERENCES: Radiography in Modern Industy, 1958, Eastman Kodak Company, Rochester, N. Y.

I. PREPARATION (of the learner)

A. Explain that most radiographer beginners subject their work uniforms to chemical stains unknowingly because their vision is obscured while processing films in the darkroom.

B. Outline further that it is possible to remove chemical stains from clothing and that this will be covered in the lesson, as well as the removal of chemical stains from the hands.

C. Stress the need for maintaining clean and safe facilities in which to work as these are the marks of true professionalism.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Processing tanks	1. List the sources of contamination: a. Chemical stain and gelatin b. Fungus and algae c. Precipitation from chemicals 2. Explain the necessity for cleanliness and sterility because of fungus growth

that can occur in chemical tanks.

3. Describe and display commercial cleaners for the removal of contamination.
4. List the chemical formulas on the chalkboard for use in removal of various contaminating agents.
5. Outline precautions to be employed in handling chemicals:
   a. Do not let chemicals remain in contact with the skin.
   b. Avoid splashing liquid or chemicals in the eyes.

B. Processing hangers

1. Describe and explain the similarity of hanger contamination to tank contamination since hangers come in contact with tank walls and with chemicals in the tanks.
2. List chemical formulas of solutions for removal of contamination on the chalkboard.
3. Detail the use of nitric acid solutions for very difficult clip stains explaining the process of soaking hanger clips in nitric acid water solution a few minutes. Then rinse with tap water. NOTE: Always add acid to water (water in the tank first)
4. Display dirty and properly cleaned hangers.

C. Stains on clothing

1. Explain that the best method of control of clothing stains is the careful handling of materials to avoid spillage.
2. Display rubber or plastic apron used to keep chemicals from clothing. Demonstrate use.
3. Describe the chemicals and methods used to remove stains from clothing. Moisten with spot remover and rinse with water. Chemical spot and stain removers all supplied by film manufacturers.
4. List the chemical formulas for stain removers on the chalkboard.
5. Caution against the use of solutions on colored fabrics and synthetic fibers since some spot removers will bleach

	out color of garment.
D. Care of hands	1. Caution against over exposure of hands to processing chemicals because they can cause skin discoloration and rash. 2. Recommend the use of gloves and disposable towels. 3. List on the chalkboard the formula for potassium permanganate solutions used to remove skin stains. 4. Describe the method of skin stain removal. 5. Demonstrate the preferred method.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Explain the necessity for periodic cleaning of processing tanks and promote discussion.

B. Explain the consequences of dirty hanger clips and how to remove contamination asking questions as explanation progresses.

C. Describe the method of removing stains from hands and clothing demonstrate and have students participate in the examples used.

IV. TEST (final check on students' comprehension of materials presented)
NOTE: Written Test

A. What is the source of contamination found in chemical processing tanks ?

B. What effect does contamination have on film processing quality ? Describe.

C. How can stains be removed from clothing ? Give examples.

D. What measures can be employed to prevent skin irritation from chemicals ?

Check and discuss.

V. SUMMARY

A. Dirty film hangers are a major cause of film artifacts.

B. Quality work cannot be maintained without a constant program of darkroom housekeeping.

C. Fresh chemicals offer no advantage if chemical tanks are not kept clean.

D. Stains on worker's hands and clothing reflect poorly on the ability of the worker.

The Next Lesson is: Insertion of Film on Processing Hangers

INSTRUCTOR'S LESSON PLAN
Manipulative Skills

Unit 18
Lesson 3
Time 1.5 hours

JOB (or operation): Insertion of Film on Processing Hangers

AIM (or purpose): To develop skill in the insertion of film into processing hangers

TOOLS AND EQUIPMENT: Darkroom facilities

MATERIALS: Clean rags

TEACHING AIDS: Sheets of 14" x 17" film (defective or outdated)
14" x 17" processing hangers
14" x 17" film cassettes or exposure holders
Brush

I. PREPARATION (of the learner)

A. Introduce the subject and elaborate on how the best radiograph can be damaged by improper insertion into processing hangers. Explain that faulty insertion can result in film becoming detached in the chemicals or dryer with subsequent damage to one or more of the other film.

B. Outline that processing camera cut film sheets is very similar to processing x-ray film and if anyone has such experience it will stand him in good stead when studying the material about to be presented.

II. PRESENTATION (of the skills)

Operations or Steps	Key Points (things to remember to do or say)
A. Assemble equipment	1. Gather hangers to be loaded. 2. Collect exposure holders or cassettes containing exposed film. (Use outdated or damaged film.)

B. Inspect hangers	1. Examine hangers for contamination. 2. Inspect clips for bits of film left from previous processing. 3. Clean hangers if necessary before proceeding using brushes, solvents and rags.
C. Position equipment	1. Turn hangers upside down and lean them against back board of work bench. 2. Clear area to stack hangers after loading them (hang from hanger storage racks if convenient). 3. Stack cassettes near the hangers allowing room for opening and stacking of unloaded cassettes.
D. Remove film from cassette (Simulate darkroom procedure while demonstrating in white light)	1. Unlatch exposure holder, 2. Remove film from holder by grasping the upper left hand corner of the 17" length between the thumb and forefinger of the left hand.
E. Pick up processing hanger (hangers are stacked upside down. Directions apply to handling in the position in which they are stacked)	1. Pick up the hanger with the right hand. 2. Grasp the clip in the upper left corner between the thumb and forefinger. 3. Steady the hanger with the other three fingers of the right hand,
F. Clip film to hanger	1. Open clip in the right hand by squeezing. 2. Insert the corner of the film held in the left hand into the clip. 3. Caution: Do not pin it too close to the edge or force it too deeply into clip. The pin should pierce the film about 3/8" from each edge of the film. 4. Reverse hands and pin the other top corner, 5. Caution: Pin both top corners in such manner that the film hangs straight in the hanger. 6. Holding the hanger upside down in the right hand, grasp the bottom left edge of the film by the thumb and forefinger

6 OF 6

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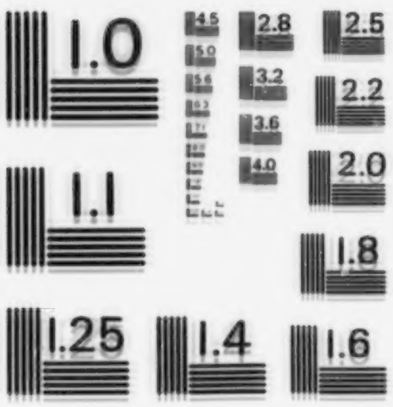
1.0
4.5
5.0
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2.0
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1.25
1.4
1.6

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

of the left hand with the bar of the hanger in the web of the thumb and the back of the hand toward the body.

7. Turn the hanger over.
8. Clip the corner held in the left hand.
9. Grasp the upper right corner with the thumb and forefinger of the right hand.
10. Clip the corner with the left hand.
11. Stack or hang the loaded hangers to avoid damage until film is loaded into processing tanks.

G. Repeat steps D, E, and F with white lights extinguished and after adjusting to darkened room	Repeat the procedure outlined above.

III. APPLICATION (practice by learner under close supervision)

A. Have each student simultaneously perform the task of inserting a film into a processing hanger several times under supervision of the teacher. Do this in a lighted room.

B. Inspect work and discuss.

C. Repeat process several times in darkened room under closest possible supervision.

IV. TEST (performance of skill to acceptable standards)

NOTE: Performance Test

Have each student insert a film in a hanger in total darkness. Repeat until all students can load film without damage and without the aid of safe lights.

Check and discuss.

V. SUMMARY

A. All preliminary steps must be planned in advance so that student will be oriented as to equipment and material location before room is darkened.

B. Hands must be washed and dried before handling film to prevent artifacts.

C. Hangers must be inspected for cleanliness before lights are extinguished.

D. Film must hang squarely in hanger to prevent bulging and subequently touching adjoining film while in the chemical processing tanks.

The Next Lesson is: Use of Film Processing Reels

INSTRUCTOR'S LESSON PLAN
Manipulative Skills

Unit 18
Lesson 4
Time 1.5 hours

JOB (or operation): Use of Film Processing Reels

AIM (or purpose): To familiarize the student with the correct use of film processing reels

TOOLS AND EQUIPMENT: Dark room facilities
Film cassettes
Reels
Plastic or stainless steel "tee" sticks

MATERIALS: Clean rags
Scrub brush

TEACHING AIDS: 70 mm film (used or outdated)

I. PREPARATION (of the learner)

A. Outline that many radiographic applications require the use of film over 17" long requiring for its processing a different type of film handler. A reel is usually substituted for the hanger in situations of this sort. Show students typical reels. There are several types on the market. Also show the students the "Tee" shaped stainless steel wire through which reels are threaded prior to immersion into chemicals.

B. Explain that the process is quite similar to that used in processing regular 35 mm film and if any of those present have experience in the processing of this size film,this exposure will be most helpful in acquiring the new skills.

II. PRESENTATION (of the skills)

Operations or Steps	Key Points (things to remember to do or say)
A. Preparation of 70 mm film	Illustrate and explain on the chalkboard that one end of the film should be trimmed with a paper cutter or scissors removing corners. This will facilitate starting the film into the grooved guides of the reels.
B. Inserting film in reel	1. The film is wound into the grooves in the reel or in the space between the wire that the reel is made of. (Show both types) The grooves act as spacers that allow the chemical solution to contact the film between each circumferential warp of the film. 2. Grooves are spaced so that properly inserted film surfaces will not come in contact with each other.
C. Demonstrate using previously developed film, in light	1. Hold the reel in one hand. 2. Place the end of the film in the clip located on the axle of the reel. Some reels have a sharp end of a nail that is forced through the end of the film. 3. Holding the side edges of the film with the other hand, between the thumb and index finger, apply slight, but steady pressure to the film to reduce its width until it is equal to the width between the reel grooves. 4. While maintaining this slight pressure on the film, start rotating the reel with the other hand,thereby feeding the film into the reel grooves. 5. After the film has been placed on the reel check to see if any film surfaces are touching. If they are, unwind the film to the point of film contact and rewind.
D. Placing reels in chemicals	1. String each completed reel of film on a "Tee" stick by threading the stick through the hollow axle of the reel.

	2. To develop film immerse the reels and stick in the chemicals. 3. Remove the film from the reels by grasping the very edge of the film with one hand and reel with the other hand and unwind it.
E. Removing developed film from reel	1. Developed film can be dried by hanging the film on an improvised clothes line made of nylon string and using plastic clothes pins. 2. If the film is dried outdoors avoid strong sunlight and dusty areas. 3. A large percentage of field radiographs are dried in this manner especially on pipeline construction jobs.
F. Reel housekeeping	Reels must be scrubbed the same as film hangers to remove contaminants

III. APPLICATION (practice by learner under close supervision)

A. Pass out reels to each student

B. Review film inserting sequence and technique by threading an 18" x 70 mm film on reel.

C. Pass out strips of film to each student.

D. Ask them to prepare film for threading as demonstrated in Step II.

E. Have each student thread film on reel.

F. Time this operation.

G. Examine each threaded reel for kinked film and for film surface contact.

H. Practice as many times as necessary.

I. Repeat E above, using exposed, undeveloped film with white lights out in dark room.

J. Process films.

K. Examine and discuss results.

IV. TEST (performance of skill to acceptable standards)

NOTE: Performance Test

A. Have students place films in film cassettes in dark room with white lights out.

B. Have students remove films from cassettes and thread film on reels.

C. Turn on lights, examine and discuss results.

D. Turn out white lights and distribute some previously exposed film that has not been developed. (Film should be in cassettes).

E. Have students remove film from cassettes, place on reels and develop.

After film have been processed, inspect each person's film on viewing screen and point out results of improper reel techniques. (Kinks, finger prints, etc.)

Remind students that film artifacts can sometimes be mistaken for specimen defects.

V. SUMMARY

A. Film preparation for aid in inserting film in reel groove.

B. Grooves separate layers of film.

C. Creases and kinks in film will cause film surface contact during processing and show up as artifacts on finished radiograph.

D. Film reels must be kept clean, especially groove surfaces.

The Next Lesson is: Film Processing Chemicals

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 18
Lesson 5
Time 2 hours

SUBJECT: Film Processing Chemicals

AIM (or purpose): To provide knowledge and information regarding the use of various chemicals in the processing of industrial radiographic film

MATERIALS: Bottles and packages of processing chemicals

REFERENCES: Radiography in Modern Industry, 1958, Eastman Kodak Company, Rochester, N. Y.

I. PREPARATION (of the learner)

Much of the students time to date has been devoted to developing a clear understanding of the principles of exposure or the taking of a good radiograph. The care exercised in the exposure must be followed by painstaking perfection in the darkroom if the fundamentals learned to date are to be fully utilized. Everyone produces better work when he understands the reasons for his actions. The principles of chemical processing will be reviewed and expanded in this lesson to help improve the procedures and processes employed in the darkroom.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Developer	1. This subject was discussed previously in the lesson plan entitled "The Photographic Process" and therefore it should be reviewed briefly. 2. Show the types of prepared chemicals available for radiographic use. 3. Explain the mixing of chemicals, especially the precautions that should be taken in mixing dry chemicals. 4. Describe the ideal storage environment for radiographic chemicals:

    a. Dry, cool room,
    b. Chemicals must not be exposed to bright sunshine,

B. Stop bath

1. Define the purpose of the stop bath and explain that it stops the alkaline developing process with an acid neutralizer.
2. Relate the acidity of the stop bath to the alkalinity of the developer.
3. Describe commercial stop baths and the use of acetic acid.
4. Caution: Use care in mixing strong acids demonstrating the proper method.

C. Fixer

1. Review the purpose of the fixer outlining that it removes all the undeveloped silver.
2. Explain the use of ammonium or sodium thiosulfate for fixing.
3. Describe the added benefits from use of commercially prepared chemicals containing agents to control the rate of reaction.
4. Outline the purpose of the hardener explaining that it conditions the gelatin so film can withstand drying with warm air.

D. Wetting agents

1. Describe the purpose of wetting agents:
    a. Wetting agents remove film water marks,
    b. Accelerates drying time,
2. Explain that household liquid detergents are sometimes used for this purpose.

E. Replenishers

1. Define the purpose of replenishing.
2. Tabulate the results in increased chemical usage from replenishing.
3. Explain the effect of replenishment on fixing and how it reduces fixing time. See Table XIII, P. 75, Eastman Textbook.

F. Supplemental

1. Describe the process of film intensification:
   a. Under developed film can be darkened by immersing it in hardener solution for 5 minutes.
   b. Film can be washed for 5 minutes then immersed in an intensifier solution for up to 10 minutes.
2. Caution students on the safe handling of strong chemicals used in these processes.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Suggest that students describe the entire and complete chemical processing of film.

B. Have individual students describe and elaborate on each step in the process.

C. Have students describe the controls employed for the reaction.

D. Ask for a description of the use of chemicals other than prepackaged that can be used in the processing of film.

E. Have one student develop a small radiograph in a set of chemicals previously prepared in jars. Reverse the sequence of the developer and the fixer, inviting a prediction of the results (Film will be clear).

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What is the purpose of the stop bath?

B. What type of film artifacts result from elimination of the stop bath or from continued use of weak baths?

C. What happens to the fixer if the stop bath is depleted or is too weak to perform its intended task?

D. What is the purpose of replenishing?

E. What is the purpose of the post-wash wetting agents?

Check and discuss.

V. SUMMARY

A. Developer should be mixed thoroughly, kept in a temperature controlled environment and not exposed to sunlight.

B. The stop bath neutralizes the alkaline action of the developer.

C. The fixer removes all undeveloped silver. Also hardens or conditions gelatin for drying in warm air.

D. Wetting agents remove water marks and accelerate drying time.

The Next Lesson is: Darkroom Film Processing

INSTRUCTOR'S LESSON PLAN
Manipulative Skills

Unit 18
Lesson 6
Time 2 hours

JOB (or operation): Darkroom Film Processing

AIM (or purpose): To assist students in acquiring the necessary skill and the proper techniques in darkroom procedure and the chemical processing of film

TOOLS AND EQUIPMENT: Film hangers
Processing tanks
Development time indicator chart
Darkroom facility
Timer
Thermometer

MATERIALS: Processing chemicals

TEACHING AIDS: Exposed or outdated film

REFERENCES: Radiography in Modern Industry, 1958, Eastman Kodak Company, Rochester, N. Y.
Nondestructive Testing Handbook, Volume I, 1963, Society for Nondestructive Testing, Evanston, Illinois

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I. PREPARATION (of the learner)

Explain that the exposure of a film is only one part of the process of producing a radiograph. The proper chemical processing of the film is equally as important as the exposure. Processing techniques do not change appreciably once the fundamentals have been mastered and repetition and practice does the rest, until ultimately the procedures become automatic reactions. It is therefore easy to see the importance of establishing good work habits from the beginning.

II. PRESENTATION (of the skills)

Operations or Steps	Key Points (things to remember to do or say)
A. Prepare processing tanks	1. Have all chemicals and materials ready to use in dark room. Establish proper temperature and prepare to demonstrate. 2. Remove lids from the tanks and store out of way. 3. Energize temperature control device. 4. Use plastic or rubber paddles to stir chemicals. 5. Replenish chemical to proper height in tanks.
B. Load hangers	Since hanger loading is covered by another lesson, review briefly.
C. Set timer	1. Check the temperature of the chemicals. 2. Use a process time indicator or chart to determine the optimum process time. 3. Set timer for the indicated time.
D. Developing	1. Pick up hangers containing film by the cross bar. 2. Caution: If more than one film is handled at a time, separate hangers with fingers. Do not attempt to handle more than three hangers at a time. 3. Lower film into tank slowly, keeping hangers vertical and separated. 4. Energize timer. 5. Agitate each film to remove air bubbles from the surface by raising hanger about 1/2" and tapping sharply on the top of the tank. 6. Agitate each film every 30 seconds by moving from side to side and up and down in tank. Better results can be obtained by lifting film clear of tank and draining from the corner. 7. Remove film from the tank and place in clear water when proper time has been reached.

	8. Accomplish Step 7 quickly as developing reaction is continuing.
E. Stopping development	Immerse film in stop bath for 30 to 60 seconds maintaining good agitation.
F. Fixation	1. Immerse film in fixing solution. 2. Agitate frequently using the same procedure as for development. 3. Allow the film to remain in the solution for twice the length of time required to clear for a pre-established time interval.
G. Washing	1. Remove the film from the fixer solution and place in the wash tank. 2. Preferably place it in the end of the tank nearest the drain. 3. Caution: Entire hanger must be immersed to remove all chemicals from the hanger as well. 4. Continue moving the film toward inlet side as more film is added to the wash tank. 5. Leave the film in the tank the length of time necessary to remove all of the fixer solution.
H. Removing water marks	1. Remove the film from the wash water and immerse it in a wetting agent. 2. Drain all excess water from the film and tap the hanger lightly on the tank to loosen all water under the clips.
I. Drying	1. Energize the film dryer. 2. Place the film in the dryer and allow it to remain until the film is thoroughly dry.

III. APPLICATION (practice by learner under close supervision)

A. Divide the students into groups of two. Have each pair run through the entire procedure using dry tanks (no chemicals).

B. Observe each group and make notations and corrections.

C. Discuss observations, give help as needed.

D. Continue practice. This time follow the same procedure but actually process undeveloped film. Give close supervision.

IV. TEST (performance of skill to acceptable standards)

NOTE: Performance Test

A. Have each student develop an exposed film under safelight conditions using the procedures outlined in the lesson.

B. Continue testing until all students have developed acceptable film and have demonstrated proper darkroom procedures.

V. SUMMARY

A. Correct film processing technique is as important as correct exposure techniques in obtaining quality radiographs.

B. Shortening of recommended processing times can only result in a reduction of quality in the radiograph.

C. Every film processing step is important if optimum results are to be obtained.

The Next Lesson is: Control of Chemical Processing

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 18
Lesson 7
Time 2 hours

SUBJECT: Control of Chemical Processing

AIM (or purpose): To furnish the student with information on methods of testing and controlling dark room chemical processing

REFERENCES: Radiography in Modern Industry, 1958, Eastman Kodak Company, Rochester, N. Y.

I. PREPARATION (of the learner)

Write aim of lesson on chalkboard and point out that many laboratories employ a system of chemical replacement on a time or film-processed basis regardless of the activity of the chemicals. Other laboratories use chemicals until the quality of the processed film is noticeably affected. Competent radiographers use more economical and scientific approaches to the replacement of chemicals and this lesson will provide the information on how this important procedure is accomplished.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Developer control	1. Explain the desirability of controlling the chemical activity of the developer. 2. Describe the procedure and list the steps on the chalkboard for developer control: a. Exposure of test film b. Preparation of test strip c. Storage of test film d. Development of test strip e. Determination of density f. Adjustment of procedure g. Preservation of standard strip

B. Stop bath control	1. Explain the method of control based on the area of film processed, noting that stop bath changes color as it weakens. 2. List on the chalkboard the area of the various types of film which can be processed with one gallon of stop bath.
C. Fixer control	1. Explain the use of emulsion clearing time to control baths which are not replenished explaining that total fixing time should be twice the clearing time. 2. Describe the limitation on replenishment cycles for discarding a fixer bath (Refer to Table XIII,P. 75, Eastman Textbook) 3. List on the chalkboard the areas of various films which can be processed with one gallon of fixer bath. See Table XIII,P. 18,Eastman Textbook.
D. Adequacy of washing	1. Describe commercial hypo test solutions for determining the amount of fixer remaining in the film emulsion after washing. 2. Inform the student of the existence of the American Standard ASA PH4.8 for precision determination of fixer remaining in the emulsion.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Start discussion and have students explain the method of developer control.

B. Have them compare the amount of film processed to useful life of a stop bath.

C. Ask students to describe the methods for determining exhaustion of fixer solutions.

D. Have the group tell why all fixer should be removed from film and how to determine the adequacy of the wash cycle.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. Why is a check system desirable for control of chemical solution activity in film processing?

B. What method is used to correct the activity of a developer if the film test strip has too high a density?

C. What is the common practice used to control fixer activity?

D. What undesirable effects restrict the repeated replenishment of fixer solutions?

Check and discuss.

V. SUMMARY

A. While recommended developing and fixing times vary, they are all based on fresh, full strength chemicals used at or near 68° F.

B. Some developer stop baths indicate a need for replacement by a change in color.

C. Developer is seldom contaminated because it is used first but liquid level must be maintained in addition to replacing spent developer with a replenishing agent.

D. Adequate cycle with a constant replacement of wash water is very desirable.

The Next Lesson is: Preparing for Field Radiography

INSTRUCTOR'S LESSON PLAN
Manipulative Skills

Unit 18
Lesson 8
Time 6 hours

JOB (or operation): Preparing for Field Radiography

AIM (or purpose): To develop skill in the procedures and precautions required to move radiographic equipment and portable darkrooms to a field location

TOOLS AND EQUIPMENT:
Portable darkroom
Motor vehicle
Gamma ray camera and controls
Survey meter, Dosimeter charger,
Film badges

MATERIALS: All film and accessories necessary to perform the radiographic functions

REFERENCES: Title 10, Federal Register, Parts 20 and 34, Rules and Regulations, U.S. Atomic Energy Commission, Washington, D.C.
Information Sheet #3

I. PREPARATION (of the learner)

Much of the success achieved in any field operation depends in large measure on careful planning before leaving for the jobsite. A professional radiographer should form the habit of checking all equipment before leaving and be able to select the darkroom location which is most convenient to the work on the site. With practice and study these good work habits can be acquired and retained. Write aim on chalkboard.

II. PRESENTATION (of the skills)

Operations or Steps	Key Points (things to remember to do or say)
A. Prepare vehicle for travel	1. Place "Caution Radioactive Materials" signs on vehicle carrying the gamma source. 2. Stow all loose materials in the darkroom in the proper bins. 3. Fill water containers with fresh water. 4. Replenish process chemicals as needed. 5. Check expendable supplies and replenish where necessary. 6. Check accessory equipment: a. Film holders b. Lead numbers c. Film hangers d. Tape e. Measuring rules f. Survey meters g. Spare chemicals 7. Fasten all covers and doors securely. 8. Load gamma source and secure in place. 9. Load film. Caution: Store film at greatest distance possible from source.
B. Travel to location	1. Select route with smoothest road surface. 2. Avoid quick stops or weaving in and out of traffic. 3. Do not leave vehicle unlocked if unattended.
C. Place vehicle on location	1. Select a level location for spotting of the portable darkroom. Caution: Do not obstruct normal traffic. 2. Place jacks under vehicle for stability if jacks are available.

D. Preparation of job site

1. Examine the work area for presence of other workmen or for instruments which might be damaged by radiation. For example: Many processing plants use control instruments that respond to a fixed amount of radiation. If another radiation field is created near this instrument, it will start to give false signals that can upset the operation of the processing unit.
2. Erect rope barricades and radiation signs. Note: Do not obstruct normal operations with barricades unless a radiation hazard does actually exist. Do not omit the barricades from areas where radiation hazards exist just because it may hinder other operations.
3. Examine area again for presence of workmen.
4. Unload the equipment to be used.

III. APPLICATION (practice by learner under close supervision)

A. Divide the class into small groups. Have each group prepare the vehicle for movement, move to a job site, and setup for performance. Have the group return the vehicle to the laboratory and place the equipment in its original condition. Supervise the preparation and movements.

B. Repeat the operations having the students tell what they are doing and why they are doing it, correct any faulty concepts or operations.

IV. TEST (performance of skill to acceptable standards

NOTE: Performance Test

A. Grade each student on the preparation of equipment and vehicle, conduct of driving, and selection of location on each trip made with the portable darkroom.

B. After each trip, discuss the conduct of the trip with the students. Indicate areas of needed improvement.

V. SUMMARY

A. It is important to use a check list when preparing for a field assignment.

B. Gamma exposure devices must be locked at all times when not in use and especially when being transported to and from field assignments.

C. Vehicle transporting gamma exposure device must have radiation warning signs prominently displayed.

D. It is desirable to pick the smoothest route to and from field location because:
   a. Chemicals can spill out of tank
   b. Survey meters can be damaged
   c. Exposure device can be damaged

E. Constant surveillance is necessary when using gamma and x-ray equipment outside a controlled area.

The Next Lesson is: Photographic Density

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 19
Lesson 1
Time 2 hours

SUBJECT: Photographic Density

AIM (or purpose): To develop an understanding of the meaning and the mathematical concepts of photographic density

TEACHING AIDS:
Light source (spot film viewer)
Film densitometer
Film density strips
Logarithm tables

REFERENCES: Radiography in Modern Industry, Eastman Kodak Company, 1958, Rochester, N. Y.

I. PREPARATION (of the learner)

The variation in film densities caused by differences in radiation intensity cause a contrast which outlines the image of the part and any possible defects. Film density is a logarithmic function which relates to the radiation absorption characteristics of the specimen. To better understand the character of the defect which alters the radiation intensity and the resultant film image, it is necessary to understand the nature of density variations. This lesson will help one gain a better understanding of these principles.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Photographic density	Write the definition on the chalkboard: "Density is the logarithm of a ratio of the amount of light striking a film compared to the amount which passes through to the other side".
B. The mathematical expression $D = \log \frac{I_o}{I_t}$	1. Write the expression on the chalkboard.

2. Also write the definition of each member of the expression on the chalkboard showing that density equals the log of light incident on the film divided by light intensity transmitted through the film.
3. Use an example to explain the use of the equation.
4. Display film strips to show differences in density. Do this with the use of a spot viewer.

C. Measuring density

1. Display the film densitometer.
2. Outline its function explaining that it measures relative film density.
3. Explain briefly the principle of the instruments operation:
   a. Measures the ratio between the amount of light reaching front side of film compared to amount of light emerging at the back side of film.
   b. That a photo cell is the basis of this method of measurement.
4. Show the instrument in operation using a film strip.
5. Demonstrate how to use the film strip to estimate the density without the necessity of performing an actual measurement:
   a. Hold film strip next to radiograph.
   b. Try to match up radiograph's density with a particular step of the calibrated film strip.
   c. Check results and discuss.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

To promote discussion and provide the basis for questioning, ask the group to answer the following statements giving one or more students an opportunity to handle each topic.

A. Define film density. Explain your definition.

B. How is density measured? How do densitometers measure density?

C. What is the mathematical equation of density?

Suggest that students solve the following problems on the chalkboard:

A. If the light entering a film has an intensity of 100 and the light coming through to the opposite side has an intensity of 10, what is the film density?

B. If the light passing through a film is reduced by a factor of 4, what is the film density?

C. If the percentage of light passing through a film is only 5% of that entering the film, what is the density?

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

Indicate the correct answer.

A. Film density is the logarithm of the reduction factor of the ____________ passing through the film.
   1. Radiation strength
   2. Radiation intensity
   3. Light emission
   4. Light intensity

B. Density is measured by determining the logarithm of the ___________.
   1. Ratio of the light entering to light leaving
   2. Ratio of the light leaving to the light entering
   3. Light intensity of the light leaving the film
   4. Intensity of the light entering the film

C. Density can be approximated by ______________.
   1. Measuring the thickness of the part being inspected
   2. Measuring the intensity of the light leaving the film
   3. Comparing the film with a density strip
   4. Approximating the intensity of the radiation reaching the film

Work the following problems:

D. The light entering a film has an intensity of 500 and the light coming through to the other side has an intensity of 50. What is the film density?

E. If the light passing through a film is reduced by a factor of 25, what is the film density?

F. If the density of a film is 2.0 and a light enters the film with an intensity of 100, what is the intensity of the light at the exit side?

V. SUMMARY

A. Radiographic relative film density is the log of the ratio of light incident on a film compared to the light emerging through the film.

B. Film densities cannot be estimated accurately on a visual basis, therefore, a densitometer should be used.

C. The radiographic film density range is important for quality work.

The Next Lesson is: Calibration of a Transmission Densitometer

INSTRUCTOR'S LESSON PLAN
Manipulative Skills

Unit 19
Lesson 2
Time 2hours

JOB (or operation): Calibration of a Transmission Densitometer

AIM (or purpose): To develop skill in calibrating and using a film densitometer

TOOLS AND EQUIPMENT: Photovolt transmission densitometer
Various types of measuring meters

TEACHING AIDS: Film density strips
Sample radiographs
Various types of measuring meters

REFERENCES: Manufacturers operating instruction manual

I. PREPARATION (of the learner)

Introduce this lesson by having students visually estimate three different relative densities on a radiograph of a steel step wedge. Record individual estimates on the chalkboard and follow up by checking the relative densities on the photovolt type densitometer. The results should be something less than accurate and this will demonstrate the importance of using a densitometer in measuring relative film density. Compare a densitometer to other type meters students should be familiar with. A densitometer is an instrument for measuring relative film density. Densitometers are of two types, visual and photoelectric. Great accuracy is generally not required in film density measurements, however, some specifications require a definite range of density for all film delivered to specification. It is necessary for the radiographer to know how to obtain the density of a film if the work is performed according to these specifications.

II. PRESENTATION (of the skills)

II. PRESENTATION (continued)

Operations or Steps	Key Points (things to remember to do or say)
A. Set up	1. Place densitometer on a table of convenient height. 2. Turn off main switch and power switch on the density unit. 3. Connect control panel to density unit. 4. Connect instrument to proper power source.
B. Zero and warmup	1. Check mechanical zero on indicating meter. Adjust if necessary. 2. Turn range switch to the lowest sensitivity setting. 3. Turn selector switch to warmup position. 4. Turn lamp control knobs on density unit full counter clockwise and energize power switch on the density unit. 5. Allow ten minutes for warmup.
C. Calibrate photometer	1. Set the pointer to the index on the high density side of the meter by electrical zero control adjustment. 2. Turn sensitivity switch to maximum and check above operation. Readjust if necessary. 3. Return sensitivity to minimum position. 4. Depress arm of density unit firmly to the aperture without a negative in position. 5. Open shutter by depressing plunger on end of arm. 6. Turn fine lamp control to midway position. 7. Make an approximate meter zero with the coarse lamp control. 8. Make final zero adjustment with fine control. 9. Release shutter and check index on high end of scale. Recalibrate if necessary.

D. Measuring density	1. Place negative on density unit table with the area to be measured over the aperture. 2. Depress the arm and open the shutter. 3. Read the density direct from the meter. 4. For density above 1.3 move sensitivity switch to proper position and add a density value equal to the number on the selector switch opposite the index mark.

III. APPLICATION (practice by learner under close supervision)

Divide the students into small groups. Under close supervision have each student in each group repeat the following demonstration:

A. Set up.

B. Zero and warm up.

C. Calibrate photometer.

D. Measure density of film.

IV. TEST (performance of skill to acceptable standards)

NOTE: Performance Test

A. Request that each student calibrate the instrument.

B. Have them read and record the density of each increment of a test strip made of a step wedge.

E. Compare their results with yours.

Check and discuss.

V. SUMMARY

A. A densitometer is a valuable aid in improving the quality of radiographs.

B. The densitometer eliminates guesswork when checking results of exposure time calculations.

C. A densitometer is often used to estimate percentage of metal loss occurring in piping subject to corrosive attack.

The Next Lesson is: Measuring Radiographic Sensitivity

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 20
Lesson 1
Time 2 hours

SUBJECT: Measuring Radiographic Sensitivity

AIM (or purpose): To outline the purpose and methods of using image quality indicators

TEACHING AIDS:
- Assorted penetrameters
- Film viewer
- Sample film showing penetrameters

REFERENCES:

Standard for Welding of Reactor Coolant and Associated Systems and Components for Nuclear Power Plants, Nav-Ships, 250-1500-1, Nov. 1960, U.S. Navy Bureau of Ships
Radiography in Modern Industry, Eastman Kodak Co., 1958, Rochester. N. Y.
Information Sheets #49 and #50

I. PREPARATION (of the learner)

Write aim on chalkboard explaining that much of the success of the radiographic operation depends on the ability of the radiographer to achieve the required sensitivity in his work. To insure that he has met the desired requirements, the radiographer must have some type of image quality indicator. The purpose of this lesson is to develop a better understanding of the various types of indicators, describe their use, and impart a thorough knowledge of the limitations of their use.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Penetrameter sensitivity	1. Write the following definition on the chalkboard: "An indication of the ability of the radiographic procedure is to indicate a certain difference in specimen thickness."

	2. Elaborate on the above definition: a. Penetrameter sensitivity does not guarantee the ability to detect a defect. b. The sharp edges of a penetrameter are more easily seen than natural defects. c. Only indicates ability to detect a thickness change. 3. Describe the generally accepted sensitivity levels of American specification (2% of the specimen thickness)
B. Penetrameter construction	1. Draw a chalkboard sketch of the various types of penetrameters including the European types. 2. Distribute a specification sheet on a typical American penetrameter. Information sheets #49 and #50 3. Explain the function of the holes and slots outlining that hole diameters are usually one, two and four times the penetrameter thickness. One or more holes should be perceptible in the radiographic image. 4. Display all available penetrameter types for student examination. 5. Explain why penetrameters should be made of similar material to that being inspected as they usually represent a 2% increase in subject thickness on the radiograph.
C. Radiographic quality level	1. Explain radiographic quality level in terms of shim thickness and hole size. 2. Standard quality level is generally designated as 2-2T. 3. To indicate 2-2T quality the 2T hole is a 2% shim must be clearly visible.

D. Placement of penetrameters	1. Explain that penetrameters are placed on the source side of the specimen because image quality indication should represent the farthest specimen-film distance. 2. Explain that shim blocks are required to achieve proper thickness since shim blocks make up difference in weld thickness and plate thickness. (Penetrameter is placed on the plate.) 3. Describe and illustrate with a chalkboard sketch the technique for determining the proper penetrameter when the penetrameter can not be placed on the source side.
E. Film quality	1. Caution students against acceptance of film quality on penetrameter image alone. 2. Outline other means of determining film quality such as: a. Freedom from light leaks b. Elimination of processing defects such as streaks, air bells, and water marks c. Cleanliness of film and freedom from dirt and scratches d. Absence of pressure marks and crimps e. Indication of poor screen contact

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Refer to specification sheet for construction of penetrameters and ask individual students to explain the various dimensions and how they are obtained.

B. To stimulate discussion ask the group the following questions, give one or more students an opportunity to answer. In the event that no answer or an incorrect one is offered,hasten to supply the correct information and give all supporting data freely. Be careful not to request answers on subject not fully covered in previous presentations:

1. What is meant by penetrameter sensitivity?
2. What is the generally accepted penetrameter sensitivity?
3. What is meant by radiographic quality level?
4. What is the generally accepted value of radiographic quality level?
5. Why is the penetrameter placed on the source side of the specimen?
6. What does a penetrameter measure?
7. What are other factors which indicate film quality?

C. Have the students view the sample film and identify the penetrameter sensivity and the radiographic quality level of each film.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

Each statement below contains a missing word or words, therefore, the missing information should be supplied.

A. Penetrameter sensitivity is an indication of the ability of a radiographic procedure to indicate a difference in specimen ______________.

B. The generally accepted radiographic quality level is _________, which means the procedure has the ability to resolve a __________ hole in a ____________ thick shim.

C. Shim blocks are used under penetrameter in weld inspection to increase the __________ of the metal to the same as the weld reinforcement.

D. Penetrameters are placed on the source side of the specimen because their image is ________________ greatest by this placement.

E. Penetrameters should be constructed of materials having similar radiation ____________ properties as the specimen to be inspected.

V. SUMMARY

A. A penetrameter is an image quality indicator.

B. An image quality indicator is used to detect a thickness change.

C. There are several shapes and sizes of penetrameters.

D. Penetrameters are placed between the source of penetrating radiation and the specimen being radiographed when feasible.

E. There are other means of determining film quality besides the penetrameter image.

The Next Lesson is: Radiographic Subject Contrast

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 20
Lesson 2
Time 2 hours

SUBJECT: Radiographic Subject Contrast

AIM (or purpose): To furnish the student with a basic understanding of the factors controlling radiographic sensitivity

TEACHING AIDS: Film viewer
X-ray exposure charts
Sample radiographic film

REFERENCES: Radiography in Modern Industry, Eastman Kodak Co., 1958, Rochester, N. Y.

I. PREPARATION (of the learner)

Since the primary purpose of most radiographic inspections is to detect defects and discontinuities in materials, a knowledge of the factors affecting the sensitivity of the procedure is quite important. The thickness of the various portions of the specimen influences the radiation reaching the film, therefore, the ratio of the intensities from different thicknesses is called the subject contrast. To study the effect of subject contrast on film sensitivity is the purpose of this lesson and its relative importance is self evident.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Subject contrast	1. Write the definition of subject contrast on the chalkboard: "The ratio of radiation intensities transmitted by different portions of the specimen." 2. Explain the definition and illustrate with a chalkboard sketch such as Fig. 10 in Radiography in Modern Industry.

	3. Explain the independence of subject contrast from time, milliamperage, distance, and film type, pointing out that subject contrast depends basically upon specimen thickness and density variations.
B. Factors affecting subject contrast 1. Thickness difference in specimen	1. Using an exposure chart, illustrate by a chalkboard sketch the range of intensities which can be produced from a specimen with a thickness difference of 2 to 1. See page 49 of Radiography in Modern Industry. 2. Display sample film showing the subject contrast obtainable from different thicknesses.
2. Radiographic quality	1. Define radiographic quality and write on the chalkboard: "The relationship between the specimen geometry and the penetrating qualities of the radiation." 2. Using an exposure chart, illustrate on the chalkboard the ratio of intensities from a specimen with a 2 to 1 thickness ratio when different kv's are used. 3. Display film showing the change in subject contrast from several different kv's.
3. Radiation scattering	1. Review the effects of scattered radiation on the overall density of the film. 2. Explain why scattering reduces contrast. 3. Explain the benefits from the use of masks and diaphragms: a. Scatter fogs film, undercuts thin parts of specimen, reduces overall contrast. b. Tends to cause a fog or haze over image. c. Masks and diaphragms absorb scatter. d. Filters absorb soft radiation that causes scatter.

4. Describe the action of filters in the radiation beam.
5. Review the actions of intensifying screens:
   a. Reduce exposure time at high kvp.
   b. Improve radiographic quality at low kv.
   c. Reduce scatter in both cases.
6. Display sample radiographs which show proper and improper control of scattered radiation.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

To promote discussion, invite the group to consider various questions. Give one or more individuals opportunity to answer, however, in the event an improper or incorrect answer is given the instructor must hasten to correct the matter and avoid such questions as reflects unexplored subject matter.

A. What are the factors which affect subject contrast?

B. What is subject contrast?

C. What is radiation quality?

D. How does scattered radiation affect subject contrast?

E. What effect does a difference in section thickness within a specimen have on subject contrast?

F. What are some of the methods of reducing radiation scattering?

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

Indicate the correct answer by writing in one of the four suggested answers.

A. Subject contrast is the ratio of the _______________ transmitted by different portions of the specimen.
   1. Gamma rays
   2. X-rays
   3. Radiation intensities
   4. Density levels

B. When the subject contrast increases, the film will respond by _________.

1. Fogging
2. Increasing contrast
3. Decreasing contrast
4. Decreasing exposure time

C. If two radiographs are made of the same test piece using different kilovoltages, the radiation intensity ratio from area of different thicknesses will be _____________ for the higher kilovoltage.

1. Higher
2. The same
3. Lower

D. Radiographic quality is the relationship between the specimen geometry and _____________.

1. The gamma ray source strength
2. The intensity of the radiation
3. The exposure factor
4. The penetrating qualities of the radiation

E. Scattered radiation reduces subject contrast by ___________.

1. Reducing exposure time
2. Producing a coherent uniform radiation
3. Intensification of the primary radiation
4. Creating a haze or fog over the image

V. SUMMARY

A. Subject contrast is the ratio of radiation intensities transmitted by different portions of the specimen.

B. The factors affecting subject contrast are: Thickness variation in specimen, radiation quality, and radiation scattering.

C. Radiation scattering effects can be reduced with filters, diaphragms and masks.

The Next Lesson is: Radiographic Film Contrast

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 20
Lesson 3
Time 2 hours

SUBJECT: Radiographic Film Contrast

AIM (or purpose): To develop a basic understanding of the factors controlling radiographic sensitivity

TEACHING AIDS: Film viewer
Characteristic curves of various film
Sample radiographs

REFERENCES: Radiography in Modern Industry, Eastman Kodak Co., 1958, Rochester, N. Y.

I. PREPARATION (of the learner)

The purpose of the radiographic inspection is generally speaking the detection of small discontinuities in a material. The radiographer is hired to perform the necessary functions to detect these small irregularities and this lesson is to help him understand the factors which affect the sensitivity of the procedure, and his ability to achieve the desired results.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Film contrast	1. Write the definition of film contrast on the chalkboard: "The slope of the characteristic curve; i.e., the ratio of density to the relative exposure of the film." 2. Explain the definition and illustrate with a chalkboard sketch of the curve. 3. Outline the independence of film contrast from the quality of the radiation. Film contrast is an inherent part of each type film

B. Factors affecting film contrast 1. Exposure time 2. Temperature 3. Agitation 4. Developer activity	1. Explain the necessity of controlling the development time to achieve full development. 2. Display films developed at various times at the same temperatures. Discuss the differences. 3. Caution against over development to achieve greater speed. Overdevelopment causes fog. 4. Remind the student of the relationship between time and temperature in developing. As developer temperature rises, development time decreases. 5. Recommend the control of temperature or adjustment of time to achieve uniform results, by controlling darkroom temperature or developer chemical temperature. 6. Display sample film developed at the same time but at various temperatures. Discuss. 7. Explain the need for maintaining fresh chemicals and compare the effects of depleted chemicals to insufficient developing time. Fresh chemicals increase production and quality. 8. Invite questions.
C. Density	1. Review the relationship between the slope of the characteristic curve and the difference in film density for various exposures. A linear relationship exists only between the heel and the toe of the characteristic curve. 2. Show by a chalkboard sketch, the method of calculating a density gradient. 3. Explain by use of the chalkboard the difference in densities obtained for an equivalent exposure of a part in an area of the curve with a low and a high density gradient. (See Fig. 75 of Radiography in Modern Industry) Heel and toe areas of a characteristic curve offer wider density ranges.

4. Discuss the slope of the curve and density of film contrast.
    a. Compare and discuss slopes of three or four different types of film
    b. Measure the range of linear relationship for each type

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III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

Oral questions following the same procedures as outline in Step III of the preceeding two lesson plans.

A. What is meant by film contrast?
Ans. The slope of the characteristic curve

B. What are the factors affecting film contrast?
Ans. Processing practices and density

C. List the processing practices which affect film contrast
Ans. Time, temperature, agitation, and developer activity

D. Why should the developing time be controlled?
Ans. Full development produces maximum film contrast, while over development reduces contrast and promotes fogging

E. Why is agitation important to control of film contrast?
Ans. Improper agitation retards development and produces streaks which obsecure the true image contrast

F. What is meant by a density gradient?
Ans. Density gradient is the instantaneous slope of a point on the characteristic curve

G. What value is a knowledge of the density gradient?
Ans. Density gradient is useful in determining the film density and contrast produced by different radiation intensities.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

Each statement below contains a missing word or words. Supply the missing information.

A. Film contrast is the ratio of the ________________ to the relative exposure of the film.

B. Film contrast is independent of ______________.

C. Over development of film can result in reduction of density and the production of an overall _____________________.

D. Time of development is directly related to the ______________ of development.

E. Lack of agitation reduces film contrast by reducing chemical activity at the surface of the film and by producing _____________ on the film.

F. The density gradient is the ________________ of the curve at a particular point on the characteristic curve.

G. Image contrast between two portions of a specimen is increased when the exposure is made in a region of the curve with a high ________________.

V. SUMMARY

A. Film contrast is defined as the slope of the characteristic curve or the ratio of the density to the relative exposure of the film.

B. Radiographic contrast is the product of subject contrast and film contrast.

C. Processing factors affect radiographic contrast.

D. Film contrast varies with each type of film.

The Next Lesson is: The Effects of Geometric Factors on Definition

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 20
Lesson 4
Time 2 hours

SUBJECT: The Effects of Geometric Factors on Definition

AIM (or purpose): To outline the factors controlling radiographic sensitivity

TEACHING AIDS: Film viewer
Samples of radiographic film

REFERENCES: Radiography in Modern Industry, Eastman Kodak Co., 1958, Rochester, N. Y.

I. PREPARATION (of the learner)

The sensitivity of a film is a function of radiographic contrast and image definition. Radiographic contrast has been treated with discussions on subject and film contrast. However, image definition is a function of geometric and graininess factors. This lesson will deal with the first of these, the geometric factors and demonstrate how they can be controlled to improve the overall film sensitivity.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Geometric factor	Define the geometric factor affecting definition as any factor which possesses dimensional measurements.
B. Geometric factors affecting sensitivity	
1. Focal spot size	Illustrate and explain the effects of changing the focal spot size on sensitivity by using a chalkboard illustration and a light source with a diaphragm closure. (See Fig. 10 of Radiography in Modern Industry)

2. Film-focal distance	1. Illustrate and explain the effects of film-focal distance by chalkboard sketch and light source. 2. Display sample film for student examination. 3. Invite questions.
3. Specimen-film distance	1. Illustrate and explain by chalkboard sketch and light source demonstration. 2. Display sample film for student examination. 3. Discuss results of film examination.
4. Abruptness of thickness change	1. Display sample radiographs with "defects" having rounded and sharp edges. 2. Explain why sharp edges are easier to detect than rounded edges. Use the density gradient for explanation.
5. Screen to film contact	1. Display sample film made with good and poor screen contact. 2. Explain the image distortion caused by poor screen contact. Use chalkboard sketch. 3. Invite questions.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Promote discussion and questions by asking the group to describe the following geometric factors and explain how they affect sensitivity. Allow one or more students to treat each factor being ready to correct any misconceptions and incorrect responses. Be careful not to request information on subject matter not covered in previous work:
   1. The focal spot or gamma source size
   2. The film to focal spot distance
   3. The film to specimen distance
   4. Abruptness of thickness change
   5. Intensifying screen to film contact

B. Ask individual students to demonstrate the first three factors using a visible light source.

C. Using the sample film, ask the students to elaborate on the possible causes of poor sensitivity on each film.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

Each statement below contains a missing word or words. Supply the missing information.

A. The specimen image will have greater ______________ as the focal spot size is decreased.

B. The specimen image is ______________ in size as the specimen to film distance is increased.

C. The image will also have poorer ______________ as the specimen to film distance is increased.

D. As the change in section thickness becomes more abrupt, the specimen image will become ______________.

E. When the screen fails to make good contact with the film, the image is blurred because the emanation ______________ from the point where it was generated.

V. SUMMARY

A. Any factor which has dimensional measurements is called a geometric factor.

B. Focal-film distance is the distance between the source of penetrating radiation and the film that is to be exposed.

C. Distance between the near side of the specimen being radiographed and the film is called the specimen-film distance.

D. Use of density gradient explains why sharp edged defects are easier to detect than rounded defects.

E. Screen must be in intimate contact with film for optimum results.

The Next Lesson is: The Effect of Graininess Factors on Definitions

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit	20
Lesson	5
Time	2 hours

SUBJECT: The Effect of Graininess Factors on Definition

AIM (or purpose): To develop a basic understanding of the factors that control radiographic sensitivity

TEACHING AIDS: Film viewer
Sample radiographic film

REFERENCES: Radiography in Modern Industry, Eastman Kodak Co., 1958, Rochester, N. Y.

I. PREPARATION (of the learner)

Throughout the career of a radiographer, he is confronted with one major problem. He must show the part to be inspected in sufficient detail to permit evaluation of its serviceability. This lesson and the preceeding three lessons cover the major factors that control sensitivity and are a complete outline of the problem. An understanding of each factor and its relationship to the others will help to eliminate many of the problems of maintaining a satisfactory sensitivity level in the finished product.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Graininess factors	1. Define a graininess factor as any influence which tends to produce a "graininess" in the image of the specimen. 2. Define graininess as the clumping of silver grains in the film to produce a visually discernable particle in the emulsion. 3. Draw a chalkboard sketch to illustrate graininess and show how it reduces film sensitivity.

B. Graininess factors affecting definition 1. Type of film	1. Explain the presence of grains in all film, all x-ray film is grainy and the faster the film the grainer. 2. Relate the speed of a film to its graininess, explaining that film speed increases with grain size. 3. Explain the desirability of using fine grain film for detecting small defects. Fine grain gives better image detail so is better for detecting small defects. 4. Display sample film. Allow students to compare grain size of various films. 5. Ask questions.
2. Types of intensifying screens	1. Describe the construction of fluorescent screens and explain how the grains in the screens cause graininess in the film image. Calcium tungstate and barium lead sulfate finely powered and mixed with a binder and coated as a thin layer on a cardboard support. 2. Compare lead and fluorescent screens and their effect on graininess. Lead screens cause no graininess when intimate contact is made with film. Calcium tungstate screens are not used with gamma rays because they cause graininess. 3. Explain the relationship between the strength of the radiation and graininess when fluorescent screens are employed. As radiation penetration increases, graininess increases when using calcium tungstate screens. 4. Display sample film for student examination to illustrate the effects of different types of screens. 5. Ask questions.

3. Radiation quality	1. Explain the effect of radiation strength in producing graininess. As penetration of radiation increases, graininess also increases. 2. Explain the rate of reaction of different types of film to high strength radiation. Graininess is increased when development time is lengthened to increase film speed. 3. Describe the use of inherent fine grain film for high energy radiation pointing out why.
4. Development	1. Explain the relation between developing time and the growth of "Clumps". A developing speed which gives a decrease in graininess will also give an appreciable loss in film speed. 2. Describe the adverse effects which accompany the practice of increasing developing time to gain film speed. Overdevelopment can cause fog and decrease contrast.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

To promote discussion invite the group to answer the following questions, giving one or more students an opportunity to answer each question. The instructor should be careful to quickly supply the correct answer in the event of misunderstanding or lack of knowledge. No questions should be asked if there is doubt that the subject was adequately covered or if the information is new or beyond the knowledge of the student:

A. Define the graininess factor and its effect on sensitivity.

B. What is graininess?

C. Explain why some films have more graininess than others.

D. Explain why fluorescent screens cause graininess.

E. Define radiation quality.

F. How does radiation quality affect graininess?

G. How do film developing practices affect graininess?

H. Select a film to be used in detecting fine casting cracks and explain why you picked that particular film.

I. Explain why you would not use a fluorescent screen with gamma rays.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

Indicate the correct word or words to complete the following statements.

A. The speed and graininess of the film are increased by __________.
  1. Increasing the time of development
  2. Decreasing the time of development
  3. Using a lower kilovoltage
  4. Increasing the ma and decreasing the time

B. Graininess decreases the sensitivity of a film by __________.
  1. Creating a fog on the film
  2. Decreasing the film contrast
  3. Accentuating large defects
  4. Obscuring small defects

C. Graininess is increased by __________.
  1. Lower energy radiation
  2. Using lead intensifying screens
  3. Shorter developing times
  4. Using higher energy radiation

D. Inherent graininess is a characteristic of __________.
  1. Fast speed film
  2. Slow speed film
  3. High contrast film
  4. Low contrast film

E. The __________ intensifying screen has little effect on graininess.
  1. Calcuim tungstate
  2. Bariun lead sulphate
  3. Zinc sulfide
  4. Lead

V. SUMMARY

A. Any factor which tends to produce graininess in the specimen image is referred to as a graininess factor.

B. Graininess is the combining of individual silver grains in the film to produce a visible particle in the film emulsion.

C. Graininess varies with:
   1. Type of film
   2. Type of screens
   3. Radiation quality
   4. Film development techniques

The Next Lesson is: Depth Localization of Defects

INSTRUCTOR'S LESSON PLAN
Related Technical Information

Unit 20
Lesson 6
Time 2 hours

SUBJECT: Depth Localization of Defects

AIM (or purpose): To develop ability to locate flaws detected through the inspection of materials

TEACHING AIDS: Film viewer
Sample film

REFERENCES: Radiography in Modern Industry, Eastman Kodak Co., 1958, Rochester, N. Y.
Information Sheet #51

I. PREPARATION (of the learner)

Often a defective part will be found which can be salvaged in the machining process if the defect is in an area where metal is to be or can be removed. The machinist will want assurance that the defect can or will be removed before commencing operations. This lesson will cover a method of determining where a defect is located.

II. PRESENTATION (of the information)

Instructional Topics	Things to Remember to Do or Say
A. Parallax	1. Place the definition of the chalkboard: "The apparent displacement of an object as seen from two different points." 2. Explain the definition. 3. Issue information sheet #51. 4. Invite questions.
B. The parallax method	1. Draw a chalkboard sketch of the set-up as shown on the information sheet, for making a flaw depth determination. Indicate on the sketch:

    a. The position of the markers
    b. The position of the source
    c. The important distances
    d. The position of the film
2. Indicate on the chalkboard what happens to the flaw image when the two exposures are made.
3. Display for student examination a sample film from a depth determination. Explain all aspects.

C. Depth calculations

1. Illustrate and explain the method of distance measurement on the chalkboard and with the sample film.
2. Discuss the mathematical calculations on the information sheet.
3. Explain the method of determining the approximate location of the defect without making calculations.

III. APPLICATION (drill, illustrations, analogies, oral questions or assignments)

A. Promote discussion with the use of the following oral questions, being careful to observe the admonitions outlined in previous lesson plans.
  1. What is the purpose of the markers on the test piece?
     Ans. A reference point for measurement of parallax.
  2. What is parallax?
     Ans. The apparent displacement of an object as seen from two different points.
  3. Why is the source shifted for the second exposure?
     Ans. To furnish a second point from which to observe the defect.

B. Give finite dimensions to the shift in image, the film-focal distance, and the focal spot shift on a chalkboard sketch. Ask each student to calculate the location of the defect.

IV. TEST (final check on students' comprehension of material presented)

NOTE: Written Test

A. What is parallax?

B. What dimensions must be known to be able to calculate a flaw depth by the parallax method?

C. If the shift in flaw location was less than one half of the top marker shift, where is the flaw located?

D. If the film-focal distance of a parallax exposure was 36" and the flaw moved 1/2" when the focal spot was moved 5 1/2", what is the distance from the bottom surface of the flaw to the bottom surface of the specimen?

V. SUMMARY

A. Initially a radiograph does not necessarily indicate the depth of a flaw or discontinuity.

B. Parallax is the apparent displacement of an object (flaw) as seen from two different points.

C. Depth of a flaw can be determined by the parallax method.

D. Approximate depth of a flaw can be determined without making calculations.

The Next Lesson is: Depth Localization of Defects

EXPERIMENT SHEET
Depth Localization of Defects

Unit	20
Lesson	7
Time	4 hours

SUBJECT:

Determination of the location of an internal defect in a metal part

NOTE:

Instructor performs all operations

INTRODUCTORY INFORMATION:

It is often desirable to know how far below the surface a defect in a part is located. The defect may be of little significance if located in an area of low stress or it may be desirable to remove or repair the defective area. The parallax method is a useful technique for localization of the defect position.

MATERIALS AND EQUIPMENT:

Gamma or x-ray source and exposure facilities
Film cassettes and film
Gamma ray survey meter
Sample part with known defect. (A casting about three inches thick with the defect near the center is preferable)
Lead numbers
Darkroom facilities

PROCEDURE:

A. Single load a film cassette with the selected film and screens.

B. Place lead numbers on the back of the part to be inspected near the outer edges and in a straight line which includes the defect.

C. Place a lead number on the top of the part about half the distance from the defect and the more distant edge in line with the numbers on the bottom.

D. Place the part on the film and position the source of radiation at a film-focal distance of 24 inches. Center the source over the part at a point which is displaced from the center line of the defect by two to four inches. Note: The distance the source is offset from the defect is not important and the amount is generally dictated by the size of the part; however, once the distance is established it must be measured with the best possible accuracy and recorded.

E. Energize the survey meter, wait for warmup, and zero the meter.

F. Determine the exposure time required to produce a density of approximately 1. 5.

G. Expose the film for the indicated length of time.

H. Return the equipment to the safe position.

I. Move the source of radiation two to four inches on the oppsite side of the defect maintaining the alignment with the lead markers.

J. Expose for the additional time to achieve the total density of 2. 5.

K. Return the equipment to the safe position.

L. Develop the film for 5 minutes at 68° F. fix, wash, and dry.

M. Examine the film on a film viewer. Note: If the image is not satisfactory for measurement of the defect position shift with the single exposure, the procedure must be repeated using two film; i. e., one for each exposure. The films then can be superimposed for viewing.

N. Record the amount of image shift in the defect image and record the results as dimension "b".

O. Record the image shift on the top marker and record and dimension "m".

P. Add the exact amount of the source shift from the center of the defect for each exposure and record as dimension "a".

Q. The film-focal distance should be recorded as dimension "t".

R. Calculate the distance "d" of the defect from the bottom surface of the part.

S. Determine if the image shift is more or less than one half of the top marker shift.

CONCLUSIONS:

A. The defect is closer to the ________________________ surface of the part because the defect shift is _______________ than half the marker shift.

B. The depth of the defect from the top surface of the part is _______________.

C. A film-focal distance of 48" would be __________________________ for this technique if the specimen is only 1/2" thick because of the ___________ _______________ shift in the position of the defect on the radiograph.

The Next Lesson is: Procedure Qualification

EXPERIMENT SHEET
Procedure Qualification

Unit	20
Lesson	8
Time	3 hours

SUBJECT:

Qualification of the techniques for double wall pipe exposure with subsequent single wall viewing

NOTE:

Instructor performs all operations

INTRODUCTORY INFORMATION:

Most specifications for radiography require the penetrameter to be placed on the source side of the part. This procedure may not by possible when making a double wall multiple exposure of pipe to be viewed as single wall or under other circumstances which preclude placing the penetrameter on the source side. To qualify a procedure with penetrameters on the film side, a test exposure is generally required on a sample of equal thickness. This exposure is to demonstrate the capability of achieving the desired sensitivity and to establish the equivalent penetrameter to be used to indicate the desired sensitivity.

MATERIALS AND EQUIPMENT:

Gamma ray (or x-ray) source and exposure facilities
Film cassettes and film
Gamma ray survey meter
Sample pipe
Penetrameters and lead numbers
Dark room facilities

PROCEDURE:

A. Single load film cassettes with selected film and lead screens.

B. Determine the pipe wall thickness.

C. Select a penetrameter for 2-2T sensitivity on the full wall thickness and a series of penetrameters ranging in thickness down to one fourth the wall thickness.

D. Place the film on a lead sheet or exposure table and tape all the penetrameters except the 2-2T to the film in a straight line near the center of the film. Align the penetrameters end to end in sequential order of thickness.

E. Align the pipe sample over the penetrameters. The penetrameters should be in line at the point of tangency of the pipe.

F. Place the full wall 2-2T penetrameter inside the pipe with the long axis parallel to the pipe. Position in order not to interfere with the image of the other penetrameters.

G. Attach lead numbers and letters to the film for the purpose of identifying the exposure.

H. Align the source tube directly over the pipe at a film-focal distance not less than seven times the pipe wall thickness.

I. Calculate the exposure time required to produce a density not less than 1.5 nor more than 3.3.

J. Attach the source tube to the camera and extend the control cables.

K. Energize the survey meter, wait for warmup, and zero meter.

L. Extend source and expose for required time.

M. Retract source, survey, and lock source in camera.

N. Remove and develop film for 5 minutes at 68°F. fix, wash, and dry.

O. Examine film on viewer.

P. If the penetrameter on the source side indicates proper sensitivity, determine the thinnest penetrameter on the film side which has a 2T hole clearly visible.

CONCLUSIONS:

A. For this exposure the ____________ penetrameter will indicate a 2-2T sensitivity when used on the film side.

B. The exposure calculation was made using a thickness of _________ to produce a film which is viewed as a thickness of ___________.

C. The sensitivity of this film will indicate 2-2T sensitivity on a thickness of ________________.

D. This qualification procedure is necessary because it is sometimes impossible to place the ____________ on the _____________ side.

The Next Lesson is: Operation of Portable Power Plants

INSTRUCTOR'S LESSON PLAN
Manipulative Skills

Unit 21
Lesson 1
Time 2 hours

JOB (or operation): Operation of Portable Power Plants

AIM (or purpose): To assist students in acquiring skill in the care, maintenance, and operation of powerplants used in field radiographic operations

TOOLS AND EQUIPMENT: Portable powerplant

MATERIALS: Fuel
Oil
Lubricants

REFERENCES: Manufacturers operating manual

I. PREPARATION (of the learner)

Many field radiographic operations rely on portable power plants to furnish power for x-ray generators and the operation of the darkroom. The success of the entire operation is dependent on the proper functioning of the power plant, therefore, the radiographer must know how to care for and operate these portable power plants to best advantage. This lesson will help to provide some basic and fundamental facts, however, it is recommended that a thorough study be made of the manufacturer's operating manual and its procedures be followed as closely as possible.

II. PRESENTATION (of the skills)

Operations or Steps	Key Points (things to remember to do or say)
A. Preparation	Place students in proper position to see and hear. 1. Check and fill crankcase with proper or recommended motor oil. 2. Check and fill oil bath air cleaner if so equipped.

3. Fill fuel tank with the correct grade of fuel.
4. Lubricate bearings which require periodic service.
5. Remove all covers from intakes and exhausts.
6. Disconnect all electrical loads from power plant.

B. Starting

1. Open fuel tank valve.
2. Close choke lever. (Some units may have automatic chokes)
3. Wind starter rope around pulley (Some units may have electrical starters and do not require hand cranking)
4. Remove ground or energize starting switch.
5. Pull starter rope with steady even motion. Repeat if engine does not start.
6. When engine starts, return choke to open position.
7. If engine is electrically cranked, return starting switch to "Run" position after engine starts.

C. Apply load

1. Turn off switches on all apparatus to be connected to power plant.
2. Engage power lines to power plant after engine has been warmed.
3. Pickup load on each apparatus as needed.
4. Caution: Do not apply load greater than the capacity of the power plant.

D. Stopping

1. Remove load from power plant.
2. Connect ground or push stop button to short circuit ignition of engine.
3. Turn off fuel line valve.
4. Allow engine to cool then replace covers on intake and exhaust.

E. Precautions

1. Never fuel engine while running.
2. Keep guards on flywheels and moving parts.
3. Do not restrict passage of cooling air to engine.
4. Do not overload power plant.
5. Have spare spark plugs available.
6. Caution: An x-ray generator cannot function properly with a fluctuating power supply.

III. APPLICATION (practice by learner under close supervision)

A. Have one student instruct another in the proper starting procedure under close supervision of teacher.

B. Alternate student and learner positions until all students have performed the operations.

C. Have each student tell what he is going to do, how he will do it and why he is doing it.

IV. TEST (performance of skill to acceptable standards)

NOTE: Written and performance test

A. Have each student outline in written form the procedure for starting a portable power plant.

B. Have each student start the engine, apply a load, stop and prepare engine for shut down.

V. SUMMARY

A. Power plants perform two separate functions in that they furnish power for the x-ray generator and for the portable darkroom.

B. Fluctuation of power to the x-ray generator will reduce quality of the resultant radiograph.

C. Maintaining a power plant in accordance with the manufacturer's recommendations should be adequate for outdoor operations.

The Next Lesson is: Shipping Radioactive Materials

INSTRUCTOR'S LESSON PLAN
Manipulative Skills

Unit 22
Lesson 1
Time 2 hours

JOB (or operation): Shipping Radioactive Materials

AIM (or purpose): To develop skill in the preparation of radioactive materials for shipment

TOOLS AND EQUIPMENT: Gamma ray source (simulate)
Screw driver, pliers, adjustable wrench
Shipping containers

MATERIALS: Labels (poison)
Straps, nails, tape, screws, etc.

REFERENCES: Transportation of Radioactive Materials, 1965, U.S. Atomic Energy Commisssion, Washington, D.C.
Information Sheet #52

I. PREPARATION (of the learner)

The shipment of radioactive materials is controlled by strict legal procedures for the purpose of avoiding injury and damage to other people. These procedures are very simple requiring only an adequate exposure to the fundamental requirements to learn them. The purpose of this lesson is to assist the individual in the development of skill in handling radioactive materials in accordance with prescribed regulations.

II. PRESENTATION (of the skills)

Operations or Steps	Key Points (things to remember to do or say)
A. Preparation of records and shipping documents	Pass out information sheet #52 and place students so all can see and hear. 1. Enter date of shipment in source location and source inventory records.

	2. Prepare packing slip indication: a. Source type b. Source serial number c. Strength of source on shipment date 3. Enclose copy of decay chart if source is not being shipped for disposal. 4. Prepare class D label (poison)
B. Prepare gamma source	1. Transfer to shipping container 2. Secure and survey container 3. Crate or package in shipping container 4. Survey the surface of shipping container with gamma survey meter. 5. Secure all closures on shipping container
C. Label shipping container	1. Place radiation signs on outside of container 2. Fill in the surface radiation level block of the class D label (poison) 3. Attach the label to the container 4. Attach the packing slip to the container
D. Notify recipient	1. Telephone, wire, or send letter to addressee informing of the shipment indicating carrier and exact route if available. 2. Notify the transportation company to pick up container.
E. Receipt of sources	1. Reverse the procedure of survey, removal from container, and entry into records. 2. Notify the shipper of receipt. 3. Store source in approved vault.

III. APPLICATION (practice by learner under close supervision)

A. Separate the students into small groups. Have each group prepare a simulated shipping container for shipment. The group should show the necessary record entries and prepare all documents. Supervise the activity very closely.

B. Have the groups exchange containers. Ask the students to now take the necessary receiving actions. Observe all procedures for exact conformity to regulations, invite questions and supervise closely.

IV. TEST (performance of skill to acceptable standards)

NOTE: Performance Test

Have the students prepare an actual source for shipment, make entry in the record book, attach all labels, and prepare notifications. If conditions permit, have students actually ship container.

V. SUMMARY

A. Federal laws govern the transport of radioactive materials.

B. Shipping containers must be properly labeled and addressed.

C. All containers must be monitored for excessive leakage of radiation.

D. Containers must be made of an acceptable material. .

E. Shipping containers must be locked.

F. Incoming shipments must be checked for leakage, quantity of material and for contamination.

Any appendices, addenda or
references called for in this
volume are included in volume
II of the same title.